

FINAL PROJECT REPORT

DEFINE AND STANDARDIZE PROCEDURES FOR CERTIFICATION OF WELD THRU PRIMERS

NSRP PROJECT SP-3-84-I

Submitted by:

**NASSCO, San Diego, CA
National Shipbuilding Research Program
Surface Preparations and Coatings Panel SP-3**

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PROJECT 3-84-1:

**DEFINE AND STANDARDIZE PROCEDURES FOR CERTIFICATION OF WELD
THRU PRIMERS.**

ACKNOWLEDGMENTS

This report documents the results of a study performed for the National Shipbuilding Research Program, a cooperative effort of the Maritime Administration, the United States Navy, the Society of Naval Architects and Marine Engineers and the U.S. shipbuilding industry.

Contributions to the project were made by various individuals at different points in time throughout this project. The National Steel and Shipbuilding Company yard, San Diego was the sight of the testing work. Penn Ship contributed in the project initiation, and the Steel Structures Paint Council, Pittsburgh supplied much needed document and data research.

We extend our gratitude to Randy Doerksen, Welding Engineer and Jerry Keener, Project Manager who did the core work of the project tests and developed the data and insights to support the proposed certification that has resulted. Also, we wish to thank Messrs. Sullivan, Hamilton, Hansen, and Schram for their various contributions and guidance throughout this effort.

This project is dedicated to the cause for further development of a total weld thru primer system and the more 'cost effective' operation of Shipbuilding and Repair in general.

For the Project Management and Staff



W.O. Appleton

FOREWORD

This project represents a segment of the work and research needed to perfect a Weld-Thru Primer that will satisfy all of the various contending needs of production. If the dry film thickness of the coating is too great, the welds will contain too much porosity to satisfy the strength requirements; if too thin and/or inconsistent, the corrosion protection required throughout steel fabrication and assembly may not be satisfactory.

VOC content in the primer leads to expensive controls and equipment commitments. Water borne primers are not totally compatible to the paint system requirements of given ships. Zinc primers seem to work better than others, but how much zinc is optimum?

There has been some success with Weld-Thru Primers, however, it is in degrees' and varies greatly from country to country, yard to yard. The point of the matter of who has a successful experience with welding through a primer in production application depends on the certification of the practice. How are the *qualifications measured, certified, maintained, and guaranteed?*

If a *Standard Certification and Testing Procedure* were developed and put in place throughout the industry, applicable to all Navy and commercial ships alike, a very significant step forward could be taken. This project was undertaken to facilitate this purpose.

NSRP Project SP-3-84-1

**TITLE: DEFINE AND STANDARDIZE PROCEDURES FOR OBTAINING
CERTIFICATION AND TESTING OF WELD-THRU PRIMERS.**

EXECUTIVE SUMMARY

The Surface Preparation and Coatings Panel (SP-3) selected and defined this project to gain insight into the parameters that govern the standardization of procedures, certification and testing methods for welding through preconstruction primers

Steel is processed in most yards to remove mill scale, rust, and any surface conditions that can affect fabrication and welding processes. If steel were delivered "clean," and not be exposed to weather conditions during storage, fabricated and welded into assemblies and blocks, then primed, we would have the IDEAL *Just In Time Process Flow, and preconstrucion primer would* not be necessary. Generally, the yards must clean steel, and, protect the surfaces with primer during storage and fabrication.

When the industry use of automatic welding is considered, the issue of the project takes on the ultimate importance. Here, the larger costs of ship construction are driven by not only the high production welding work volumes, but also the steel surface areas to be protected throughout the fabrication/assembly cycles, as well as, the on-block and on-board cycles. This protection must be effective prior to application of other *paint* system coatings. Large costs result from re-blast, conditioning, and re-priming where the original surface protection is insufficient.

When primer is welded through, the welding heat "decomposes" the paint, creating gases that are then trapped in the weld. These gasses are manifested as spherical, piping (worm hole), and other porosities. These voids adversely affect the strength of the welded construction. Qualifying tests such as MIL STD 248 and ABS Rules for Building and Classing Steel Ships are in use for the determination of acceptability of weld-thru primers, but these are not at issue. Whether a primer is acceptable or rejected is purely a result of properly applying the test procedures.

The scope of this project was intended to reach beyond the narrow statement and definition of any given test, to study the effect of methodology, procedural practice and content, and to make comparisons with testing conducted by both U.S. and foreign sources, and arrive at the best practice.

Some informed professionals say that a satisfactory weld thru primer is impractical, while other sources claim various degrees of tested success. The NSRP has a 1992 project committed to "Development of a Comprehensive Weld Thru Primer System." By doing the informational search, evaluation of conflicting data, performing preliminary testing, analyzing variable effects, and determining standardized methods and criteria for qualification of primers this project could directly enhance the ultimate goal.

PROJECT APPROACH.

The activities that made up the work of this project were divided into four categories:

- | Documentary search and evaluation to set forth the best available facts concerning qualification and testing of successful weld thru primers.
- | Identification and acquisition of potentially usable primers.
- * Testing, evaluation of test data, and summation of test results and conclusions.
- | Develop a proposed *Certification of Weld-Thru Primers* as applied to Shipbuilding and Repair.

A discussion of each of these activities make-up this report.

CONCLUSIONS.

This project has successfully developed, through testing, a recommended certification procedure. The testing that was performed did not determine a totally satisfactory *weld-thru primer*, but did identify three promising coatings. It collected useful data from the fourteen primer coatings that were involved. The detailed project test information will be provided to the Program Manager as a separate deliverable.

The MIL STD 248, used by the Navy, is different from the ABS Rules in many details. The most significant is that the former is specific to weld-thru primer applications and the latter, to fillet welding in general without specificity to weld-thru primer qualification. The project team believes that this should be the same for both, and therefore a *Standard Certification*.

A special report by the Steel Structures Painting Council deals with a current data review entitled *WELDABLE PRIMER FOR SHIP CONSTRUCTION*.

It should be noted that NASSCO is utilizing the project testing procedure as part of a yard Production Department program to further advance weldable primer testing.

TESTING

INTRODUCTION

This project was intended to find a procedure that could provide the Shipbuilding and Repair industry a standard for certifying the use of weldable primers. The Navy had established MIL STD 248 but since it is specifically a welding standard it does not cover the detail for preparation and film thickness control of the coatings.

Therefore, starting with MIL STD 248 and ABS Rules, the project work centered on testing experiences to gain the insight needed to determine what had to be added to the existing procedures. Or, was a whole new *approach* needed?

The early experiences were frustrated due to the fact that the DFT (dry film thickness) was difficult to control. The DFT is critical to the total testing process and current production methods were generally not “tuned” to the tight windows required (0.8 to 1.2 mils). It was decided that the test specimens had to be coated by a third *party* who was separate from the *yard project team*, who underwent qualifying performance tests. This experience is important to both certification and production development work that a yard may undertake.

The welding and testing efforts went well. However, one series of tests did show clearly that the DFT, when inconsistent, yields poor, difficult to interpret results.

The testing was broken into Five Phases:

Phase I Preliminary Test was a *getting started effort* with ten primers tested in manual and semi-automatic welding processes.

Phase II Preliminary Test was the continuation of the first with eight primers tested in semi-automatic welding processes.

Phase III Preliminary Test was the continuation of II and used the automatic welding process.

Phase IV Qualification Testing planning: the selection of a third party to do the specimen coating, selection of three primers from previous tests, and election of the weld and test methods.

Phase V Qualification Testing was the final testing performed in the project and was made with three primers tested in the automatic welding process.

TESTING DISCUSSION

The project did not attempt to make any determination concerning the primers before the initial test. There was a total attempt by the project team to be open about the coatings and not work to any preconceived notions. Therefore the primers were coded so that in the final report there is maintained an anonymity in identifying the specific coatings used in various phases. Generic descriptions of the products are supplied.

USABLE PRIMERS

The preliminary tests were conducted in two parts: Phase I (the initial test) and Phases II & III (re-test for controlled film thickness). In the first test, ten primers were used. The second test used eight (8) primers. There were four (4) primers common in the Phase I and II tests.

The primers* are classified into four groups:

- | | |
|------------------------------|--------|
| 1. Waterborne Zinc..... | 6 each |
| 2. Water Thinned Epoxy | 4 each |
| 3. Hi VOC..... | 2 each |
| 4. Other..... | 2 each |

* *Test Data and Analysis Sheets show the detail, Table 3, Page 34.*

The experience here suggests the lack of weld thru primers (only four common to both tests), therefore the need for a strong paint industry involvement in the pending project, "Development of a Comprehensive Weld Thru Primer System." It should be noted, that although the same primers were not used throughout the tests, this had little impact on these particular tasks. However, it is viewed that future testing will benefit from consistent use of the same primers.

It was decided that only three primers would be used in the final phase of the project. This was due primarily to the need to conserve project funds and the lack of any real need to include previously *poor performing* coatings.

PRELIMINARY TESTING

The preliminary tests were needed to gain first hand experience with all the parameters involved. The following is an overview of the tests.

The MIL-STD-248D and A.B.S. Rules for Building and Classing Steel Vessels 1990 were followed. These may prove to be totally adequate within the originally developed scope for certifications. This project is not questioning the validity of these and other rules, but utilizing existing rules and practices to discover what needs to be included, expanded, or added.

The criteria and requirements followed are in Exhibits A, B, C, D, & E contained in this section. Experiences in this testing suggest that DFT(Dry Film Thickness) at 0.8 to 1.2 mils is difficult to control in production and, after Test 1, the coating operation was relegated to a subcontractor for controlled thickness, (the production application of the coating could have been perfected, however, production schedules and time did not permit this). The control was important to the project work to reduce the number of variables within any test sequence.

THE TEST RESULTS to this point in the tests were inconclusive, (See Exhibits B, D, & E for test summaries). However, the project was very much ON TRACK. The following information was determined:

4. Phase I tested 10 primers in two Manual, four Semi-automatic, and two Automatic Modes with general results;"
 - * Manual welding PASSED for ALL primers.
 - * Semiautomatic and Automatic welding yielded scattered results with only four primers showing some degrees of promise. Simultaneous welding of two sides in semi-automatic mode was the criteria used.
 - * One primer showed promise in most modes and was strong in the Automatic mode.
 - ** The weakness of this experiment was the variation in DFT.
2. Phase II tested eight primers in five Semi-automatic Modes, and one Automatic Mode. Note, the Manual Mode was deleted since Phase I showed that this was not an immediate issue, and conservation of resources at this time was desirable.

The results are as follows:

- * Welding procedures and methodology consistency was improved through the experience gained in the Phase I work.
- * Semi-automatic welding showed no trend in porosity (size/amount) between the first and second sides.
- * Primers vary narrowly from filler to filler. Good performance with one filler on a specific primer tends to carry through to other fillers.
- * The problems in this phase were: the number of common primers used in the Phase I and Phase II preliminary tests, only four of fourteen total were common; a variation in test reporting and the absence of a pre-planned regime. All of these were the result of working in uncharted waters, and did not affect the following work.

EXHIBIT A

TEST I OBJECTIVES, CRITERIA AND RESULTS

Test Objectives:

1. Get the testing program started without a great deal of predetermined parameters.
2. Bring in as many primers as possible for the initial testing experience.
3. Test for fracture in DFT of 0.8 to 1.2 roils, and 1.6 to 2.4 roils.

Criteria: MIL STD 248D paragraph 4.4.1.12.

FILLET WELDS-WELDING OVER PRIMER-COATED SURFACES. When this standard is specified in the applicable fabrication document, procedures for welding over primer coated surfaces of S-1 materials with any process using a previously qualified procedure shall require additional qualification in accordance with figure 9. The test assembly shall be welded with the type and largest diameter electrode to be used. Weld quality shall be considered acceptable provided visual inspection of the fractured weld surface does not reveal more than 5 porosity indications (including both "wormholes" and "porosity? larger than 1/16 inch diameter in any 1 inch of weld. Any indication larger than 3/32 inch is unacceptable and the test assembly shall be rejected.

Figure 1 is shown in Exhibit B, pg 9

ADDITIONAL QUALIFYING CRITERIA, PROCEDURES, and TESTS RESULTS are contained in Exhibit B on the following pages.

EXHIBIT B

CRITERIA FOR QUALIFICATION OF WELD-THRU PRIMERS

SURFACE PREPARATION of STEEL TEST SPECIMEN

Surfaces were prepared to the SSPC-SP-10 standard, from Steel Structures Painting Council (SSPC), Volume 1, to a surface profile of 2-2.5 roils, obtained with steel abrasive Shot S230 (NBS Screen No. 18-20).

SSPC-SP-10 dictates the surface to be cleaned with abrasives to a Near-White Blast. This requires the surface when viewed without magnification, to be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and any other foreign matter, except discoloration.

Staining must be restricted to no more than 5% of each square inch of surface area and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied paint.

PREPARATION REQUIREMENTS

Dry film thickness readings must fall in a range of 0.8-1.2 roils. If any pieces have readings out of this range, weld test pieces should be marked appropriately.

FIT-UP REQUIREMENTS

Base and standing web is to be straight and in intimate contact and securely tacked at ends before fillet-weld is made, to insure maximum restraint.

WELDING REQUIREMENTS

Plates shall be welded in the horizontal position and will qualify for all positions. The fillet is to be of the required contour, free from undercutting or overlap. Gas shoots and linear porosity are an immediate indication of a primer caused defect, and are unacceptable.

FRACTURE REQUIREMENTS

Primer test results are recordable provided the control surface meets the acceptability requirements set by both standards. Visible porosity, incomplete fusion at the root corners and inclusions may be acceptable, provided the total length of these discontinuities does not exceed 10% of the total length of the weld. Any porosity larger than 3/32" is unacceptable and when indications larger than 1/16" exceed five per inch the weld is unacceptable.

Primer evaluation will also include observation of these characteristics: arc stability, spatter, slag removal, and bead appearance.

The testing criteria used followed the guidelines set by Mil-STD-248D paragraph 4.4.1.12.

1. Plating shall be either ordinary or higher strength steel as specified in Mil-S-22698 which qualifies the procedure for use on these materials.
2. Plating shall be primer coated to maximum thickness that will be applied in production.
3. Plate shall be welded in the horizontal position and shall qualify for all positions.
4. Remove first side weld by gouging or mechanical means and fracture second side weld. Test assembly may be cut into shorter lengths after welding to facilitate fracturing for examination.

PHASE I

TEST METHOD	WELDING PROCESS	CONSUMABLES	Coating Codes									
			9.01	9.02	9.03	9.04	9.05	9.06	9.07	9.08	9.09	9.10
Fracture	Manual Shielded Metal Arc	7018 1/8"	P/F	P/P	P/F	P/P						
		7024 5.5 mm	F/F	P/P	F/F	P/P						
	Semi-Auto Flux-Cored (1)	E71T-1 (A)	F/F	F/F	F/F	F/F	F/F	P/P	F/F	F/F	P/P	F/F
		E70T-1 (B)	F/F	F/F	F/F	F/F	F/F	P/F	P/F	F/F	P/F	F/F
	Semi-Auto Flux-Cored	E71T-1 (A)	F/F	F/P	P/F	P/P	P/F	F/F	P/P	P/P	P/P	P/F
		E70T-1 (B)	P/P	F/F	F/F	F/F	F/F		F/F	P/F	P/F	F/F

Table 1

Results are shown as X/Y: X is for single coating {one mil target"}, Y is for double coating {two mil target };

(A) - Alloy Rods

(B) - Trimark

DFT tolerance ± 0.2 mil

(1) - Welding was performed on both sides of the joint simultaneously.

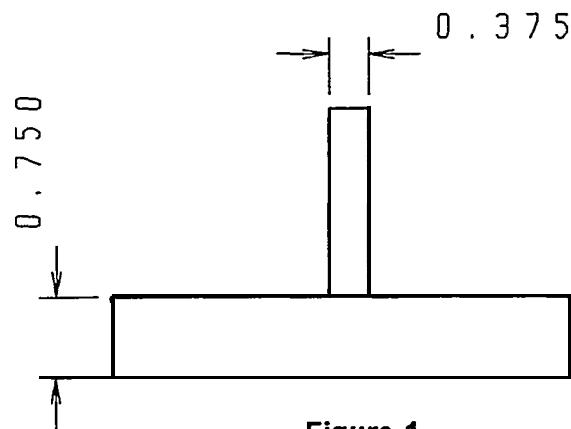
JOINT DESIGN

Figure 1

OBSERVATIONS .

Simulation of a dual-head automatic welding process (1) produced 15 rejected tests while the other semi-automatic tests produced 8 rejects. This being an indication of the primers increased reactivity with increased heat- input.

Underlined results indicate tests which are acceptable under one criteria but are rejected under the other.

Localized areas of porosity, spread unevenly thru the joint length was common, an indication that steel profile and film thickness consistency are crucial to effective weld -thru primer evaluation.

EXHIBIT C

TEST II OBJECTIVES, CRITERIA AND RESULTS

Objectives:

1. Concentrate on semi-automatic welding, drop the manual welding that proved successful in Test L
2. Add four new primers, not previously tested.
3. Perform T-JOINT fracture testing, as *in* Test I, and add the SQUARE BUTT root bend and tensile testing.
4. Relegate the coating operation to a contractor for better control of the 0.8 to 1.2 Mils DFT.
5. Expand the experience of Test L

Criteria: MIL STD 248D paragraph 4.4.1.12.

ADDITIONAL Qualifying CRITERIA, PROCEDURES, and TEST RESULTS are contained in Exhibit D on the following pages.

EXHIBIT D

PHASE II

JOINT DESIGN	TEST METHOD	WELDING PROCESS	CONSUMABLES	9.03	9.07	9.08	9.09	9.11	9.12	9.13	9.14
T-JOINT	Fracture	Semi-Auto Flux-Cored & Gas Metal Arc	E71T-1 (A) E70T-1 (B) 70S-6 (C) E70T-1 (D)	F F P F	F P F P	F F F F	P P P F	F F F F	F F F F	F F F F	
SQUARE BUTT	Root Bends	Semi-Auto Flux-Cored & Gas Metal Arc	E71T-1 (A) E70T-1 (B) 70S-6 (C)	P P P	P P P	P F F	P P P	P P P	F P F		
	Tensile	Semi-Auto Flux-Cored & Gas Metal Arc	E71T-1 (A) E70T-1 (B) 70S-6 (C)	F P P	F P P	P P P	P P P	F P P	P P P	F P F	F P F

Table 2

- (A) - Alloy Rods
- (B) - Trimark
- (C) - L-Tee
- (D) - Alloy Rods

ABSTRACT

The square butt joint is an AWS option to fillet weld test. (shown below figure 2). This joint design was selected for both root bend and tensile test.

The Root Bend Tests were evaluated using Mil-Std-248D welder performance qualification.

Weld metal tension test were performed on 3/8" X 1" specimens and evaluated using the electrode classification strength.

SQUARE BUTT JOINT

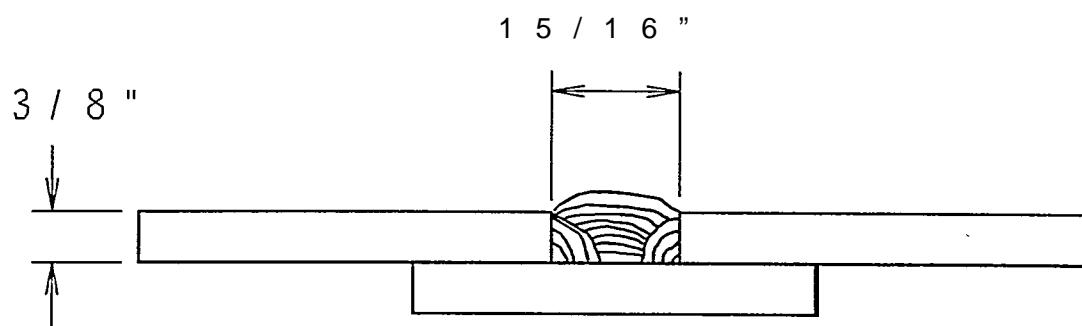


Figure 2

OBSERVATIONS

Most of Root Bend Tests met the acceptability requirements, but these results do not support the Fracture Test results.

Weld metal Tension Test results were varied and no conclusions could be drawn until further research is conducted.

PHASE II

SEMI-AUTOMATIC

TYPE OF WELD

TEST METHODS

T-JOINT

Dimensions: (a) 3/8" X 6" X 24"
 (b) 3/4" X 6" X 24 X 24"

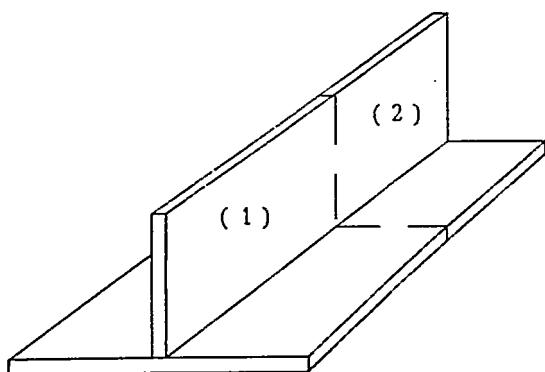


Figure 3

A.

TWO FRACTURES
(1) 1st side
(2) 2nd side

B. Macro-etch

C. X -Ray

D. Two Root Bends

E. Reduced-Section Tension

II DOUBLE FILLET SQUARE BUTT JOINT

Dimensions: (a) 3/8" X6" X5"
 (b) 3/8" X6" X5"

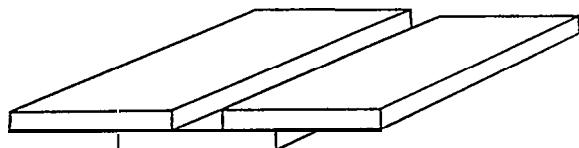


Figure 4

PROCESS

CONSUMABLES

SHIELDING GAS

FCAW	Trimark, TM-771	.052"	CO ₂
FCAW	Trimark, Metalloy 70R	.052"	CO ₂
FCAW	Hobart, Fabco 87	.052"	CO ₂
FCAW	Alloy Rods, Dual Shield 7001	.052:"	CO ₂
G MAW	Imperial, 70 S-6	.045"	AR/CO ₂

TYPE OF WELD	<u>AUTOMATIC</u>	TEST METHODS	
T-JOINT Dimension: (a) 3/8" X 6" X 3' (b) 3/4" X 6" X 3'		A. THREE FRACTURES (1) 2nd side (2) 1st side (3) 2nd side	
<u>PROCESS</u>	<u>CONSUMABLES</u>	<u>SHIELDING GAS</u>	
FCAW FCAW	Trimark, TM-771 Trimark, Metalloy 70R	5/64" 3132"	CO ₂ CO ₂

EXHIBIT E
TEST III OBJECTIVES, CRITERIA, AND RESULTS

Objectives:

1. Test for Tensile strength.
2. Determine relationships between tested tensile strength and porosity.

Criteria: MILITARY SPECIFICATION MIL-E-24403/ID, Mechanical Properties Requirements.

Results: The Tension Tests resulted the strength values measured in PSI for the Weld Consumables as indicated.

Primer Code	METALLOY 70R	DUAL SHIELD	70S-6 WIRE
9.03	77,130	67,858	77,738
9.07	80,415	66,155	75,064
9.08	88,705	71,265	65,572
9.09	83,679	73,015	70,953
9.11	83,771	67,953	64,536
9.12	83,138	72,948	
no coating	80,901		65,777

Table 1

TESTS IV& V

QUALIFICATION TESTING

The preliminary testing experience indicated that a comprehensive planning effort should take place before the initiation of what would be the final testing work. The team was concerned about decreasing, or at least closely controlling, the variables, and to get the maximum benefit from the dollars remaining in the project.

The early tests had provided the availability of primers the experience associated with DFT a focus on welding methodology and production and a better understanding of the strength test relationship. These got the project going and set the stage for understanding the many issues that could affect a good *certification procedure*.

Qualification tests centered on the approach where a small number of primers should be employed, the welding methodology should have principal importance, and direct and indirect factors that may affect certification *testing* should have maximum attention.

THE PRIMER SELECTION was intended to be three primers that previously had performed successfully, or would possibly offer new insight. In one case the manufacturer altered a coating so that an effect might be evaluated.

Coatings selected were: 9.09 a water borne inorganic zinc which tested well in Phases I, II, & III; 9.03 a water borne epoxy which consistently welded with high porosity failure; and 9.06 a water borne zinc which was reformulated for the test, (the zinc was deleted).

These coatings were then randomly assigned to the Phase V test schedule:

<u>Code</u>	<u>Test Designation</u>
9.03	I
9.09	II
9.06	III

Table 2

DFT TARGETS were set at 0.5, 1.5, and 2.5 mils (+ or - 0.2 mils), to allow for a correlation of porosity, shear and tensile strength(s).

WELD DESIGNS were called out according to the test objective:

FRACTURE	T-JOINT
TENSILE	1/2" SQUARE BUTT JOINT
SHEAR	FILLET WELD FOR SHEAR

* See Exhibit F (figures 5, 6, & 7), for the details.

A word about the strength testing is in order. Some reviewers of the project at various points had shown a concern about tensile testing since the production application for this type welding places the weld in shear, rather than tension. The team simply felt that while this was a research project by definition, and that engineering properties for materials are generally stated in tensile strength, it would be worth while to make some correlation to this to see if there was any relative value. Shear testing had been planned from early in the project, it was also recommended by others. This was added to the qualification testing and included in the test data. Both parameters could prove worth the effort.

THE TEST RESULTS are many and should be reviewed considering the two general objectives: Specifically, (1) *Developing a Standard Certification Procedure*, and implied, (2) *Supplying test information to be used in furthering the development of a Weld Thru Primer Total System*.

STANDARD CERTIFICATION METHOD

1. This project showed that the application and the control of the primer coating and the ultimate OFT are extremely critical to successfully welding through the primer.

Therefore, this needs to be addressed via stipulation of the primer application method, the OFT target, and verification of the same.

2. Surface preparation in like manner was critical and therefore deemed to be stipulated, (see description on pg 7).

3. Strength testing, while valuable in the context of the project, are not considered necessary in the context of the actual certification procedure. The strength is reflected in the allowable porosity, however, in the development of this allowance *strength verification* relative to porosity should be done.

4. The specifics of the *production welding process* need to be detailed in a manner consistent to the operation being certified.

5. Such functions as storage should also be addressed.

In other words, the testing experience showed that a certification process must mirror the actual production process to which the certification will apply. This is not the case in various existing rules such as MIL-STD-248 which is a weld standard only.

(Refer to the PROPOSED CERTIFICATION PROCEDURE pg 26, for more details.)

TECHNICAL INFORMATION

1. More Tensile and Shear testing could be desirable. Conclusive relationships were not possible due to the number of tests that could be run. The results were satisfactory and showed that valuable information can be gained via this process.
2. Porosity increases with increases in DFT; increases differently from primer to primer; and increases differently for different consumables.
3. Shear Strength generally decreased with increases in DFT (and porosity).
4. Tensile Strength did not vary as markedly as Shear Strength vs. DFT, however, this may be due to many possible factors: the test specimen process and machining, and the degree of porosity produced in the butt weld configuration versus the shear weld configuration.

(Refer to EXHIBIT F for test details, charts, etc.)

EXHIBIT F

WELD-THRU PRIMER STUDY SP-3 REPORT, COCOA BEACH OCTOBER 23, 1992

In Phases I, II, & III, analysis of four destructive tests (Fracture, Macro, Root Bend, and Tension Tests) with two criteria (ABS-Rules for Building Steel Vessels, and MIL-STD 248D) has prepared the direction for the final two phases.

Testing guidelines and procedures were established in Phase IV. The T-Joint Fracture specimen and two types of mechanical strength specimens are the tests selected. The significance of these tests are described this way. The T-Joint specimen provides the best method of accounting for the number, types, and sizes of primer produced porosity. The mechanical tests show what effect porosity has on both the tensile and shear strength of filler material.

Three primers were selected based on previous results because they showed a range of weldability from poor to good. Each primer was applied at three thicknesses, 0.5, 1.5, & 2.5 mils DFT.

All joints were fit tight to ensure no air gap existed before tacking. The Flux-Cored Arc Welding Process was used and evaluation of two consumables one of which is flux-cored and the other metal-cored.

The T-Joint (Figure 5, pg 22) is 2 feet in length. The weld leg size target for all tests is 114". After welding, the specimen is prepared for fracture testing by first removing the second side with the air-arc process. The specimen is then cut in half for two, one foot fracture tests. A detailed account of all porosity is then collected on data sheets for each test performed (Figure 6, pg 23).

The joint design for the tensile test is a 1/2" square butt joint (Figure 7, pg 24). The first two passes of this test are fillets by design. The weld leg size for each pass is just over 1/4" to ensure center-line fusion. Figure 7, pg 24 shows the joint design for the shear strength test. The weld leg size target for all tests is 1/4".

The opportunity to see what incremental increases in DFT have on increased levels of porosity can be seen. A rating system is established that is used to classify amounts and sizes of porosity per joint, Table 5, pg 39 shows the application severity level system). Each fracture test is rated using this method. The photographs taken show the vertical members of two different tests. Both the tensile strength and shear strength values are matched with the severity level of the fracture test which is common with respect to primer, welding consumable, and DFT. From this understanding is gained of the effect various porosity levels have on filler metal weld strength.

Note: Test data is contained in the Test Data Appendix, starting on page 36.

FILLET WELD FRACTURE TEST

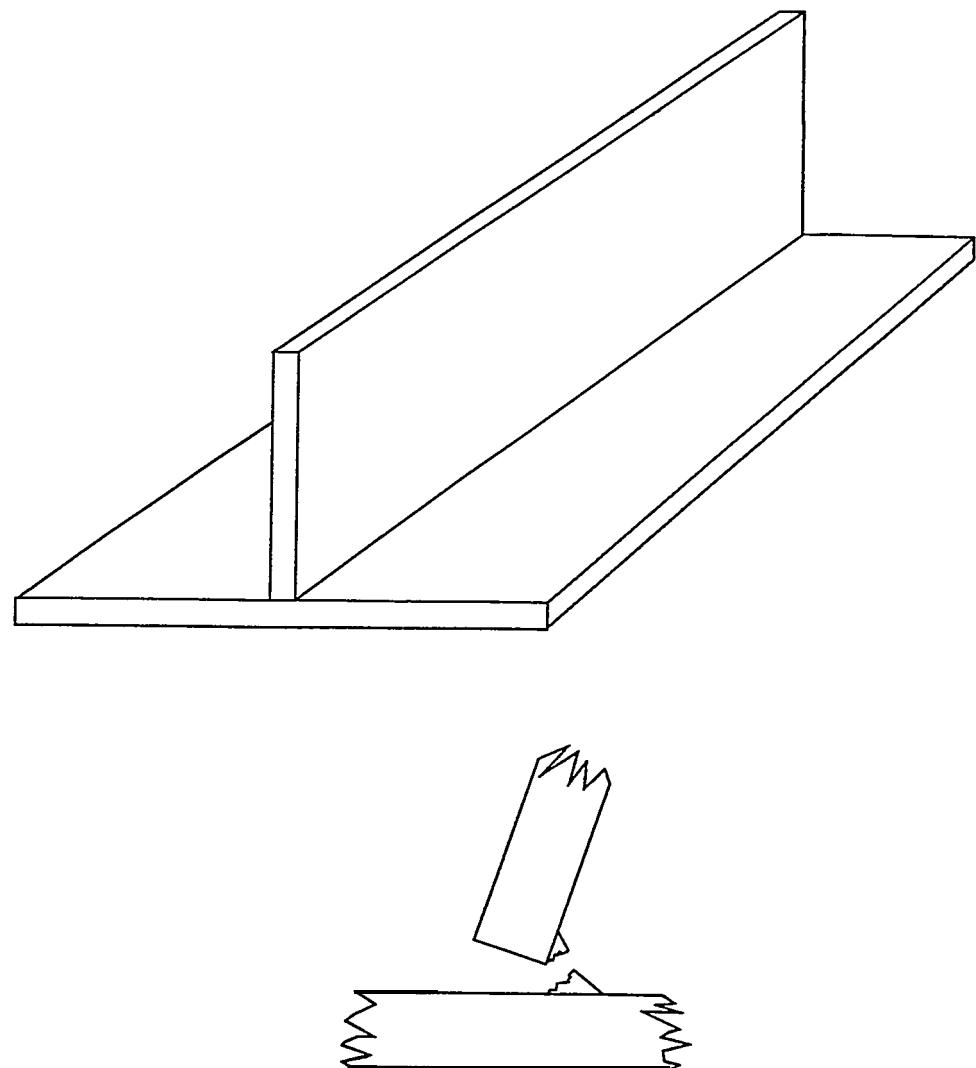


FIGURE 5

Tensile Strength Test

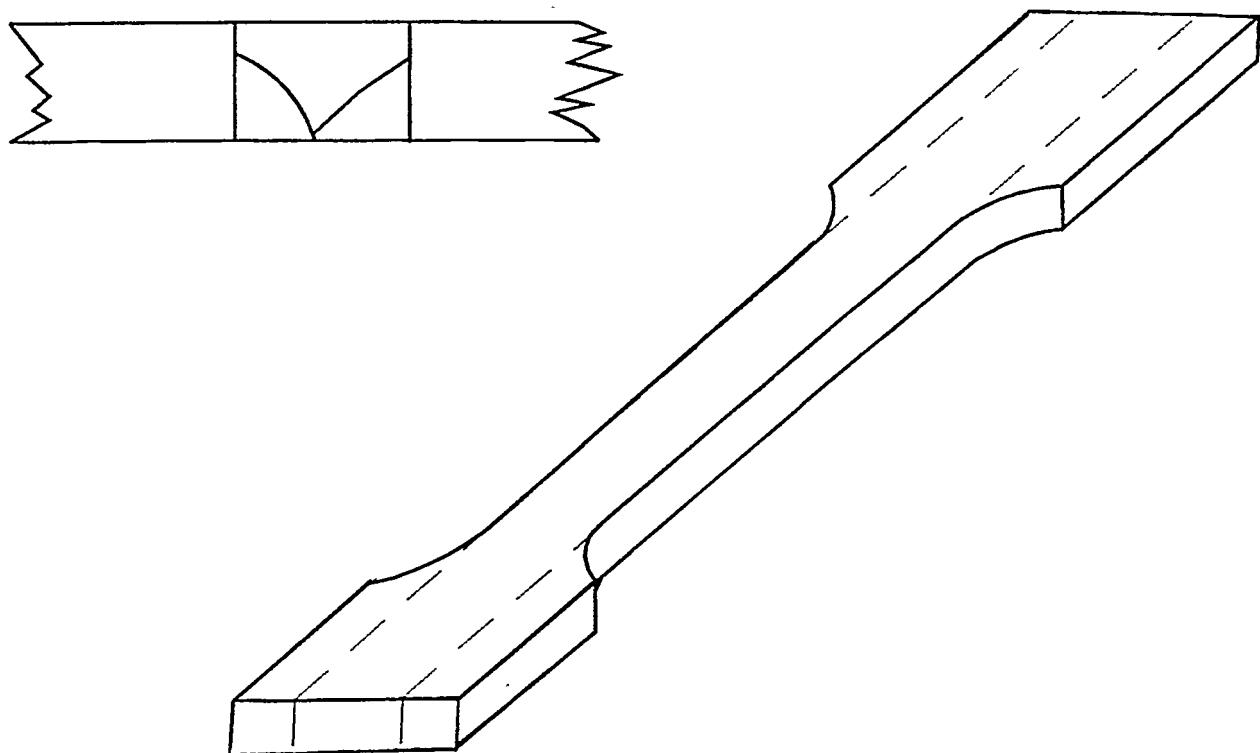


FIGURE 6

$$\tau_1 = \frac{P_{\max}}{A}$$

$$\tau_2 = \frac{P_{(0.002\text{ offset})}}{A}$$

P_{\max} = Maximum Load

P = Load at 0.2% offset

A = Original cross-sectional area

τ_1 = Ultimate tensile strength

Fillet Weld Shear Test

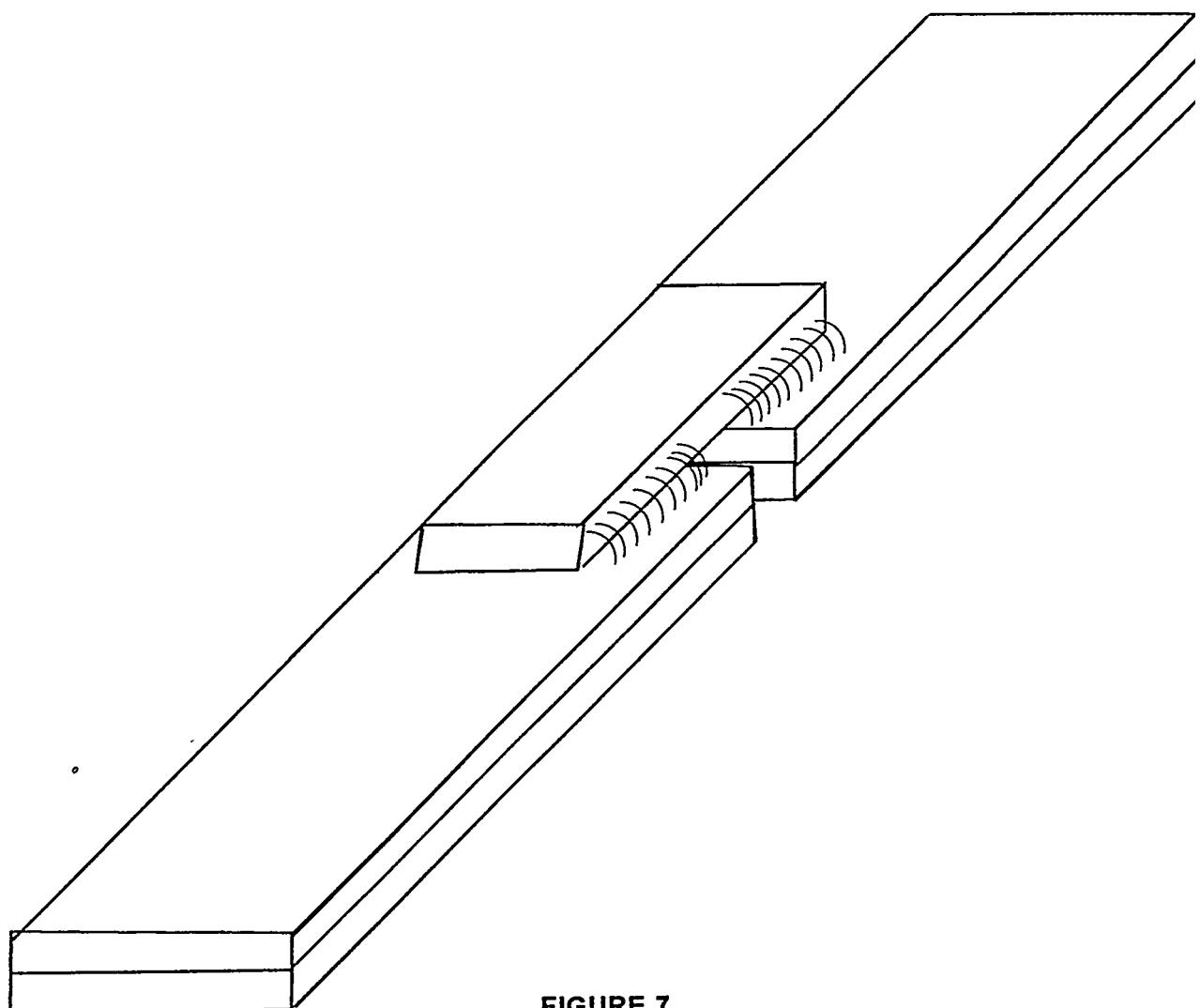


FIGURE 7

$$\tau = \frac{P}{Ia}$$

P = Load

I = Total length of fillet weld sheared

a = Theoretical throat dimension

τ = Shear strength of weld

OBSERVATIONS

The testing can be generally viewed as successful except strength tests for TEST III. The conclusions are as follows:

1. Weld thru primer criteria must include *porosity elongation* and diameter as part of the qualification if there is no specific limit placed upon throat area porosity.
2. Variations in square butt weld tensile strength did not exceed 6,000 psi over the test mil targets of 0.5, 1.5 and 2.5 respectively.
3. Although test results were inconclusive weld throat porosity, either spherical or wormhold, did impact the shear weld strength. A minimum shear strength reduction of 10,000 psi was experienced only when the throat area porosity exceeded 40% of the throat area.

The Weld Metal Tensile Strength test was not a consisive method of evaluation. The primer generated porosity evident in the Fracture Tests did not drop the Tensile Strength as the porosity levels increased. This method of destructive testing did not support visual Fracture Test results in regards to size and quantity of weld throat porosity.

More research of destructive testing methods, shear and tensile is necessary for a more complete understanding of piping porosity, and the affects on weld metal strength. The criteria of Mil-STD-248D concerning qualification of weld-thru primers is provided, and cannot be disputed. Mil-STD-248D provides allowances for porosity on a per inch basis with size and quantity specified. One pore dimension not in the criteria is pore elongation. Pore elongation averaging 1/32" versus 3/32" is significant.

Establishment of the test method, and criteria used in the procedure qualification of a weld-thru primer requires further analysis. The specific limits for porosity, both size and quantity have not been determined in this report. More research is recommended, and encouraged to be included in testing and evaluating weld-thru primers.

Additionally, the testing program achieved the project objective to "Define and Standardize Procedures for Certification of Weld Thru Primers" and develop a proposed written **standard** procedure for Certification of a Weld Thru Primer.

I earnestly hope that this work has contributed to the current and future efforts relative to Weld-Thru Primer Qualification Testing Procedures, and the "Development of a Comprehensive Weld-Thru Primer System."

Respectfully submitted:

Randy Doerksen, Project Engineer, NASSCO

CERTIFICATION PROPOSAL

Proposal

Certification of Weld Thru Primers As Applied to Shipbuilding and Repair

Premise

A Standardized Testing Method is necessary so that Weld Thru Primer practices can be certified across the industry with consistency and confidence in the results.

Discussion

This project confirms not only the need for such standardization, but also the emphasis on all aspects of the process: the selected coating, surface preparation, coating thickness control, welding process, and test method. The intention of the use of the primer coating is also important to the certification process: Is the primer to become an integral part of the finished coating system? Or, is the primer to be removed before the application of the full coating system? If the former is the case, the testing should address the total coating system.

Should a certification process confirm that process or the actual yard manufacturing process? If the testing is performed on specimens that have not been coated by the production process but are welded according to the production welding process, it follows that only the welding process has been confirmed or rejected as the case may be. This specific project was not able to test all phases of the program using specimens coated via the production method. This was due to a combination of production schedule conflicts, time to develop "finely tuned" control of coating thickness, and project time constraints. However, any certification of the production process should address the coating thickness (DFT) and the source of application.

What about Quality Assurance (QA) after a process is certified? Shouldn't the production work be monitored to confirm performance to the original certification?

Tensile and shear testing was performed in this program. This was not totally satisfactory due to the number of tests that could be scheduled, prepared and performed. However, these did support the relevance of decreases in weld strength with increases in porosity. The relationship of strength to porosity was never in doubt, but there was a desire to know the actual strength measurements for various primers and consumables. This is important in future project work but may not be required in a standard certification process.

Data Required for Certification Testing Process

The following is an inventory of information that might be needed in a comprehensive Certification Process.

Steel/Surface Preparation:

- * Plate sizes, grades.
- * A statement of the surface requirement.
- * Blast media.
- * Blast application method.

Coating: * A statement of the coating and application specification.

- * Identify the coating.
- * Coating part of the total system?
- * Coating not part of the final system, to be removed prior to application of the final coating system?
- Method of application.
- * DFT required.

Curing: * Curing cycle before welding.

Weld Process:

- * Method of application: Manual, Semiautomatic, Automatic.
- * Type of welds to be certified.
- * Weld consumables (rods, wires, sizes, gases, etc.).
- * Maximum continuous weld length.

Test Process:

- * Size of test specimens.
- * Method of cutting to length.
- * Method of breaking.
- * Method of porosity counting.
- * Method of recording.

References- MIL-STD-248D; A.B.S.- Rules for Building and Classing Steel Vessels; Canadian Coast Guard (Draft) Standard for Weldability of Preconstruction Primer.

INTRODUCTION

This certification procedure is intended to qualify the production coating and welding processes applicable to any preconstruction /weld thru primer as used in shipbuilding. The preparation and testing required in this certification are directed to both the initial qualification of a process and production quality assurance of the same.

To the welding process, primer is an impurity just as is mil scale, dirt, oil, and rust; primer causes porosity in the welds. The degree to which this porosity affects the satisfactory performance of the weld as an integral part of ship construction is set forth as "passable" limitations in MIL-STD 248D. This certification incorporates these same porosity limits.

The degrees of difficulty in this welding process are a function of multiple factors, such as:

- Surface preparation of the steel.
- Coating type and manufacture.
- Coating application and Dry Film Thickness.
- Welding process and consumables..
- Fit of steel parts in the process.

This certification procedure is to be used for each distinctive coating and weld process as dictated by specific coating, weld process, or weld consumable.

(Editorial Note: There are probably any number of limitations and categorical statements that should ultimately be included at this point.)

1.0 DEFINITIONS

1.1. WELD THRU PRIMER or PRECONSTRUCTION PRIMER is a protective coating applied to a prepared steel surface before fabrication processing to control and diminish corrosion before application of final paint systems.

Such primers may be removed before application of the final paint system or may become an integral part of the system.

WELD THRU refers to process applications of welding without the removal of the coating.

1.2. BLAST PROFILE defines the specific condition to which the steel surface is prepared before coating.

1.3. DRY FILM THICKNESS or DFT is the measured coating thickness after the curing period. The DFT must be "Targeted" to a MIL thickness that is compatible to both the coating manufacturer specification and a weldable condition. A range, HIGH and LOW, of DFT must be established which can consistently yield a MEAN DFT.

1.4. PRIMER is the coating material which is either removed before application of the paint system or the first coating application within a PAINT SYSTEM.

1.5. FINAL PAINT SYSTEM is that total set of coatings, to be applied according to various specific procedures, that makes up the total finished surface protection of the steel.

1.6. WELDABILITY is the measure to which a specific weld process can be applied to a precoated steel. This is measured according to specific test requirements as set forth in this certification.

1.7. WELD JOINT DESIGN is "T-Joint." See figure 5, pg 22

1.8. WELD PROCESS is either manual, semi-automatic, or automatic welding.

1.9. WELDING CONDITIONS are the consumables, shielding gas, voltage, amperage, and travel speed. Specification of these parameters is the basis for this certification and become a recorded part thereof.

2.0 COATING of TEST MATERIALS

2.1. Surface preparation and coating applications of the test specimens shall be performed in the exact production process that will be employed for production steel plates. This constitutes a "certification of the production blast and prime coating operations."

2.2. The blast profile shall be the maximum expected in production and the target coating thickness shall be the maximum DFT to be used in production.

2.3. Verification and recording of the blast profile, DFT, and coating specification, and manufacturer, are required.

2.4. Both lateral and edge surfaces shall be coated to the targeted DFT. The DFT must be measured for the horizontal member, the bottom edge of the vertical member, and both lateral surfaces of the vertical member in the weld joint area. Measurements shall be made to the Steel Structures Painting Council SSPC-PA2 (Specification for measuring dry film thickness with magnetic gauges). The same calibrated gauges used in the test procedure must be used in the production application.

3.0 STORAGE PERIOD for PRIMED TEST MATERIALS

3.1. The coated test specimens shall be stored in the exact manner as under production conditions for the required curing time (*) prior to application of the welding process.

* This is based upon the coating manufacturer specification.

4.0 WELDING of TEST MATERIALS

4.1. The test specimens shall be of mild steel.

4.2. The specimen width shall in accordance with diagram A, and the thickness be equal to the minimum plate thickness expected in this production application.

4.3. The coated specimens shall be cut to 24" test lengths.

4.4. Test specimens are welded in "T-Joint" configuration with a tight fit between the vertical member edge and horizontal member lateral surface. Gaps are not acceptable. The specimen assembly is tacked two places at each end and two places in the center, six tack welds in all. Single pass filets are required, all welds made in the horizontal position.

4.5. The edge condition of the vertical member must be the same as that required and provided in production.

4.6. The test assembly shall be welded with the type and largest diameter electrode to be used in production.

4.7. The welding conditions must match the expected peak heat input levels to be attained in production. Therefore, the voltage, amperage, and travel speed must be recorded and made a part of this certification.

5.0 TESTING of TEST SPECIMENS

5.1. The 24" test specimen shall be cut in half and prepared for two one foot fracture tests. For manual and semiautomatic processes, gouge the first side welded and fracture on the second side of the first specimen. For the second specimen, gouge the second side and fracture on the first side. For automatic dual head processes, gouge the first side welded for both specimens, and fracture on the second side for both specimens.

6.0 ANALYSIS of TEST WELDS

6.1. Weld quality shall be considered acceptable provided visual examination of the fractured weld surface does not reveal more than 5 porosity indications (including both "wormholes" and "porosity") larger than 1/16" in diameter in any one inch of weld. Any indication larger than 3/32" is unacceptable.

6.2. Gas shoots appearing in the surface are unacceptable.

6.3. Failures of any of the above criteria cause the test assembly to be rejected.

TEST DATA APPENDIX

TEST DATA AND ANALYSIS

Paint Codes and Generic Make-up

<u>CODE</u>	<u>Water Borne Inorganic Zinc</u>	<u>Water Borne Epoxy</u>	<u>Other Type</u>
9.01	X		
9.02			WATER BASED RUST CONVERTER
9.03		X	
9.04		X	
9.05		X	
9.06	X		
9.07			SOLVENT BASED INOROANIC ZINC
9.08	X		
9.09	X		
9.10			WATER BASED RUST DEOXIDIZER
9.11			SOLVENT BASED EPOXY
9.12	X		
9.13		X	
9.14	X		

Table 3

TEST DATA AND ANALYSIS

COATING PERFORMANCE BY TEST

OVERVIEW RATING

<u>iCODE</u>	<u>TEST I</u>	<u>TEST II/III</u>	<u>TEST IV/ V</u>
9.01	0		
9.02	0		
9.03	0		
9.04	0		
9.05	0		
9.06	#		#
9.07	+	+	
9.08	+	0	
9.09	#	#	#
9.10	0		
9.11		0	
9.12		0	
9.13		0	
9.14		0	

Table 4

The Codes represent the following ratings:

- # VERY PROMISING: performed well for the test requirements.
- + MARGINALLY PROMISING: showed some performance.
- 0 POOR PERFORMANCE: showed little to no performance.

7/22/92

NSRP - WELD-THRU PRIMER QUALIFICATION

PHASE IV& V WELD TESTS

ABSTRACT Three joint designs will be used: Square Butt 1/2"gap, Square Butt with no gap, and Tee-Joint.

Three primers selected for this research are, 1 water borne epoxy, and 2 water borne inorganic Zinxs.

Preliminary Testing
Weld Metal Tension Tests

ABSTRACT Three consumables evaluated on uncoated material. Three weld tests will be performed for each consumable. The same number of tests will follow on one type of coated material with one DFT.

PURPOSE: Observation of the effect primer has on tensile strength values and the consistency of these values compared with the uncoated specimens.

JOINT DESIGN: SQUARE-BUTT, 1/2" gap

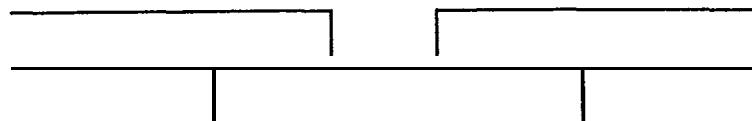


Figure 8

PREPARED TENSILE SPECIMEN:

PROFILE: 2.0 -3.0 roils

DRY FILM COATING: .5 -1.0 mil

MATERIAL Grade A Steel

AMT. of MATERIAL: Uncoated -20 ft Coated -24 ft

FILLER MATERIAL: Alloy Rods 7100 CO₂
Trimark Metalloy 70R 75125Ar-CO₂
Imperial 88 70S-6 CO₂

	<u>Alloy Rods</u>	<u>Trimark</u>	<u>Imperial</u>
UNCOATED MATERIAL:	3 Tests (A1,A2,A3)	3 Tests (A4,A5,A6)	3 Tests(A7/A8,A9)

COATED MATERIAL:	3 Tests (B1,B2,B3)	3 Tests (B4,B5,B6)	3 Tests (B7,B8,B9)
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PHASE II&V Testing Guidelines

Surface Preparation and Coating Requirements:

For DFT measurements only, certified glass testing coupons are permitted for qualifying a peak film thickness. In addition, a surface profile measurement is required for qualifying a maximum profile permitted in production.

STEEL SURFACE FINISH

The mating surfaces will be cleaned to a white metal blast. These surfaces will be coated with a controlled film thickness that meets the requirements of that test. The critical surfaces include the plate side and edge which are in or near the weld surface area.

For procedure qualification, surfaces must be blasted and coated under the most stringent of requirements. An explanation of this means the steel profile and DFT measurements will meet the highest expected conditions in production.

Before fracturing the specimen, the weld face must be inspected for gas shoots, if any exist the test specimen is unacceptable. Upon inspection, if no gas shoots appear, the specimen is prepared for fracture evaluation.

Qualification requires use of the largest diameter electrode which will qualify all smaller diameters for that specific product.

A - All -Weld Metal Tension Test

The tension test specimens shall yield results conforming to the mechanical requirements established for that filler.

B- Longitudinal Fillet Shear Strength Test

C - Fillet Fracture Test

Fracture test shall yield no more than three pores, not exceeding 3/32" in diameter per inch. For 1/4" fillet, wormholes cannot exceed elongation of 1/2 the Throat Length.

Requalification is required when elongation of porosity exceeds one half the throat length. For a fractured specimen to be evaluated effectively this fracture must occur thru the throat area, otherwise retesting is required.

Edge condition of shape must match that used in production. No joint gap is permitted during qualification testing. Tight fit-up must be achieved with clamps if necessary.

IDEA

Show how depth of penetration affects amounts of porosity generated. This can be illustrated with the lead/lag data collected from the panel line.

Welding conditions and techniques affect amount of generated porosity.
Altering welding techniques under similar conditions have effect on porosity.

Describe edge condition and it's effect on the weld porosity.

TEST JOINT ASSEMBLIES

1. The Tension Test Joint is assembled so that intimate contact is accomplished along the full length of the joint. Tack welds are placed on back side of joint assembly.
2. The Shear Test Joint is assembled so that intimate contact is accomplished along the fillet joint with tack welds placed at both ends of the vertical leg member.
3. The T-joint is assembled so that no gap is permitted between members.
Two tacks will be placed at both ends of the fitted members.

TEST METHOD

Consistency of the welding technique used and common welding parameters for all tests are critical to the successful evaluation of primer induced porosities and their effect on the weld metal strength.

SHEAR STRENGTH TEST

Welding Consumable	DFT (mils)	SHEAR STRENGTH (psi)	POROSITY LEVEL		THROAT AREA POROSITY		
			X	Y	X (in ²)	Y (in ²)	(X+Y)/2 (in ²)
PRIMER I							
Con A	0.5	72,647	P _B	F	.14	.20	.17
	1.5	66,185	F	F	.26	.24	.25
	2.5	60,288	F	F	.52	1.32	.92
Con B	0.5	65,872	P _O	P _O	0	0	0
	1.5	58,092	F	F	.56	.78	.67
	2.5	42,032	F	F	.83	1.71	1.27
PRIMER II							
Con A	0.5	66,872	P _A	P _A	.03	.01	.02
	1.5	67,252	P _A	P _A	.06	.05	.055
	2.5	75,658	P _B	P _B	.17	.11	.14
Con B	0.5	60,664	P _A	P _A	.01	.01	.01
	1.5	57,214	F	P _B	.11	.07	.09
	2.5	67,879	F	P _C	.33	.37	.35
PRIMER III							
Con A	0.5	69,761	P _C	P _C	.09	.05	.07
	1.5	55,646	F	F	1.04	.62	.83
	2.5	60,664	F	F	1.11	.48	.795
Con B	0.5	60,602	F	F	.14	.25	.195
	1.5	54,454	F	F	.63	.6	.615
	2.5	51,029	F	F	.81	1.14	.975
WELD SURFACE CONDITION APPLICATION SEVERITY LEVEL							
1. Definitions are per 12 inches of weld. 2. EACH TEST SPECIMEN WAS CUT INTO TWO TEST SAMPLES, X & Y 3. SHADED AREAS INDICATE DATA USED FOR GRAPHS 4. * CONSUMABLE A = Con A CONSUMABLE B = Con B							
Pass / Fail Criteria LEVEL P _O : A weld, free of any surface porosity, which is equal to or less than 1/64." LEVEL P _A : 5 Pores 1/32"/inch, Max Diameter 1/16" LEVEL P _B : 5 Pores 1/16"/inch, Max Diameter 3/32" LEVEL P _C : 5 Pores 3/32"/inch, Max Diameter 1/8" LEVEL F: Unacceptable							

Table 5

TENSILE STRENGTH TEST

Welding Consumable	DFT (mils)	TENSILE STRENGTH (psi)	YIELD STRENGTH (psi)	POROSITY LEVEL		THROAT AREA POROSITY		
				X	Y	X (in ²)	Y (in ²)	(X+Y)/2 (in ²)
PRIMER I								
Con A	0.5	73,479	57,150	P _B	F	.14	.20	.17
	1.5	68,735	46,379	F	F	.26	.24	.25
	2.5	70,933	50,276	F	F	.52	.32	.42
Con B	0.5	66,381	48,502	P _O	P _O	0	0	0
	1.5	63,024	40,480	F	F	.56	.73	.645
	2.5	64,581	40,355	F	F	.83	1.71	1.27
PRIMER II								
Con A	0.5	66,488	50,540	P _A	P _A	.03	.01	.02
	1.5	71,181	53,890	P _A	P _A	.06	.05	.055
	2.5	68,250	50,284	P _B	P _B	.17	.11	.14
Con B	0.5	70,165	52,486	P _A	P _A	.01	.01	.01
	1.5	72,485	53,254	F	P _B	.11	.07	.09
	2.5	67,839	47,413	F	P _C	.33	.37	.35
PRIMER III								
Con A	0.5	70,571	56,285	P _C	P _C	.09	.05	.07
	1.5	70,099	51,813	F	F	1.04	.62	.865
	2.5	76,565	60,183	F	F	1.11	.48	.795
Con B	0.5	71,639	55,719	F	F	.14	.25	.195
	1.5	70,471	54,455	F	F	.53	.60	.565
	2.5	70,891	50,636	F	F	.20	.14	.17
WELD SURFACE CONDITION APPLICATION SEVERITY LEVEL								
1. Definitions are per 12 inches of weld. 2. EACH TEST SPECIMEN WAS CUT INTO TWO TEST SAMPLES, X & Y 3. SHADED AREAS INDICATE DATA USED FOR GRAPHS 4. * CONSUMABLE A = Con A CONSUMABLE B = Con B								
Pass / Fail Criteria LEVEL P _O : a weld, free of any surface porosity, which is equal to or less than 1/64." LEVEL P _A : 5 Pores 1/32"/inch, Max Diameter 1/16" LEVEL P _B : 5 Pores 1/16"/inch, Max Diameter 3/32" LEVEL P _C : 5 Pores 3/32"/inch, Max Diameter 1/8" LEVEL F: Unacceptable								

Table 6

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER I, CONSUMABLE A

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	0	81	1/32	3/8 T	3/32	0.14	P _B
0.5 B	1	51	3/64	1/2 T	1/8	1.20	F
1.5 A	3	67	3/64	1/2 T	5/32	0.26	F
1.5 B	1	63	3/64	1/2 T	1/8	0.23	F
2.5 A	2	78	1/16	1/2 T	1/8	0.52	F
2.5 B	17	106	3/32	3/4 T	5/32	1.32	F

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

WELD SURFACE CONDITION
APPLICATION SEVERITY LEVEL

1. Definitions are per 12 inches of weld.

Pass / Fail Criteria

LEVEL P_o: A weld, free of any surface porosity, which is equal to or less than 1/64".

LEVEL P_A: 5 Pores 1/32"/inch, Max Diameter 1/16"

LEVEL P_B: 5 Pores 1/16"/inch, Max Diameter 3/32"

LEVEL P_C: 5 Pores 3/32"/inch, Max Diameter 1/8"

LEVEL F: Unacceptable

Table 7

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER I, CONSUMABLE B

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	0	0				0 **	0
0.5 B	0	0				0 **	0
1.5 A	11	68	3/32	1/2 T	1/4	0.56 ***	F
1.5 B	21	63	3/32	3/4 T	5/32	0.73 ***	F
2.5 A	48	50	1/8	3/4 T	1/4	0.83	F
2.5 B	58	62	5/32	1.0 T	3/8	1.7	F

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

** A path of gas retreat has been formed in the throat.

*** Some porosity could be classified as spherical.

WELD SURFACE CONDITION
APPLICATION SEVERITY LEVEL

1. Definitions are per 12 inches of weld.

Pass / Fail Criteria

LEVEL P₀: None Present

LEVEL P_A: 5 Pores 1/32"/inch, Max Diameter 1/16"

LEVEL P_B: 5 Pores 1/16"/inch, Max Diameter 3/32"

LEVEL P_C: 5 Pores 3/32"/inch, Max Diameter 1/8"

LEVEL F: Unacceptable

Table 8

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER II, CONSUMABLE A

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	0	31	3/64	1/4 T	1/16	0.03	PA
0.5 B	0	13	1/32		1/16	0.01	PA
1.5 A	0	39	1/16	1/4 T	1/16	0.06	PA
1.5 B	0	35	1/16		1/16	0.05	PA
2.5 A	0	54	1/16	1/2 T	1/16	0.17	P _B
2.5 B	0	44	3/64	1/2 T	3/32	0.11	P _B

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

** A path of gas retreat has been formed in the throat.

*** Some porosity could be classified as spherical.

WELD SURFACE CONDITION APPLICATION SEVERITY LEVEL
1. Definitions are per 12 inches of weld.
Pass / Fail Criteria LEVEL P: None Present LEVEL P _A : 5 Pores 1/32" /inch, Max Diameter 1/16" LEVEL P _B : 5 Pores 1/16" /inch, Max Diameter 3/32" LEVEL P _C : 5 Pores 3/32" /inch, Max Diameter 1/8" LEVEL F Unacceptable

Table 9

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER II, CONSUMABLE B

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	0	4	1/16		1/16	0 .01	P _A
0.5 B	0	8	1/16		1/16	0 .01	P _A
1.5 A	5	31	1/32	3/4 T	1/16	0.11	F
1.5 B	0	30	1/32	1/2 T	3/32	0.07	P _B
2.5 A	5	51	1/16	> 3/4 T	5/32	0.33	F
2.5 B	0	34	1/8	3/32 T	5/32	0.37	F

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

** A path of gas retreat has been formed in the throat.

*** Some porosity could be classified as spherical.

WELD SURFACE CONDITION
APPLICATION SEVERITY LEVEL

1. Definitions are per 12 inches of weld.

Pass / Fail Criteria

LEVEL P_o: None Present

LEVEL P_A: 5 Pores 1/32"/inch, Max Diameter 1/16"

LEVEL P_B: 5 Pores 1/16"/inch, Max Diameter 3/32"

LEVEL P_C: 5 Pores 3/32"/inch, Max Diameter 1/8"

LEVEL F: Unacceptable

Table 10

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER III, CONSUMABLE A

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	0	49	3/64	1/4 T	1/8	0 .09	P _c
0.5 B	0	45	1/32	1/4 T	1/8	0 .05	P _c
1.5 A	3	88	3/32	3/4 T	5/32	1.04	F
1.5 B	7	78	1/16	3/4 T	1/8	0.62	F
2.5 A	> 20 †	> 100	1/16	1/1 T	1/8	1.11	F
2.5 B	4	58	1/16	3/4 T	1/8	0.48	F

† Not countable

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

** A path of gas retreat has been formed in the throat.

*** Some porosity could be classified as spherical.

WELD SURFACE CONDITION
APPLICATION SEVERITY LEVEL

1. Definitions are per 12 inches of weld.

Pass / Fail Criteria

LEVEL P_o: None Present

LEVEL P_A: 5 Pores 1/32"/inch, Max Diameter 1/16"

LEVEL P_B: 5 Pores 1/16"/inch, Max Diameter 3/32"

LEVEL P_C: 5 Pores 3/32"/inch, Max Diameter 1/8"

LEVEL F: Unacceptable

Table 11

NSRP SP-3-84-1
WELD-THRU PRIMER

FILLET FRACTURE TEST
12" LENGTH

TEST IDENTIFICATION NUMBER: PRIMER III, CONSUMABLE B

DFT (mils)	Gas shoots	Porosity (# of pores)	Ave Dia	Ave * Elong	Max Dia	Throat Area Porosity	Porosity Rating
0.5 A	2	22	3/32	1/2 T	5/32	0 .14	F
0.5 B	11	25	3/32	3/4 T	5/32	0 .25	F
1.5 A	13	42	1/8	3/4 T	5/32	0.63	F
1.5 B	11	40	1/8	3/4 T	3/16	0.60	F
2.5 A	20	49	1/8	3/4 T	3/16	0.81	F
2.5 B	13	55	5/32	3/4 T	1/4	1.14	F

† Not countable

All Elongation in the throat region unless noted.

* This dimension represents the gas pore elongation. This is represented as (elongation)X(T). T is = to the throat length.

** A path of gas retreat has been formed in the throat.

*** Some porosity could be classified as spherical.

WELD SURFACE CONDITION
APPLICATION SEVERITY LEVEL

1. Definitions are per 12 inches of weld.

Pass / Fail Criteria

LEVEL P₀: None Present

LEVEL P_A: 5 Pores 1/32"/inch, Max Diameter 1/16"

LEVEL P_B: 5 Pores 1/16"/inch, Max Diameter 3/32"

LEVEL P_C: 5 Pores 3/32"/inch, Max Diameter 1/8"

LEVEL F: Unacceptable

Table 12

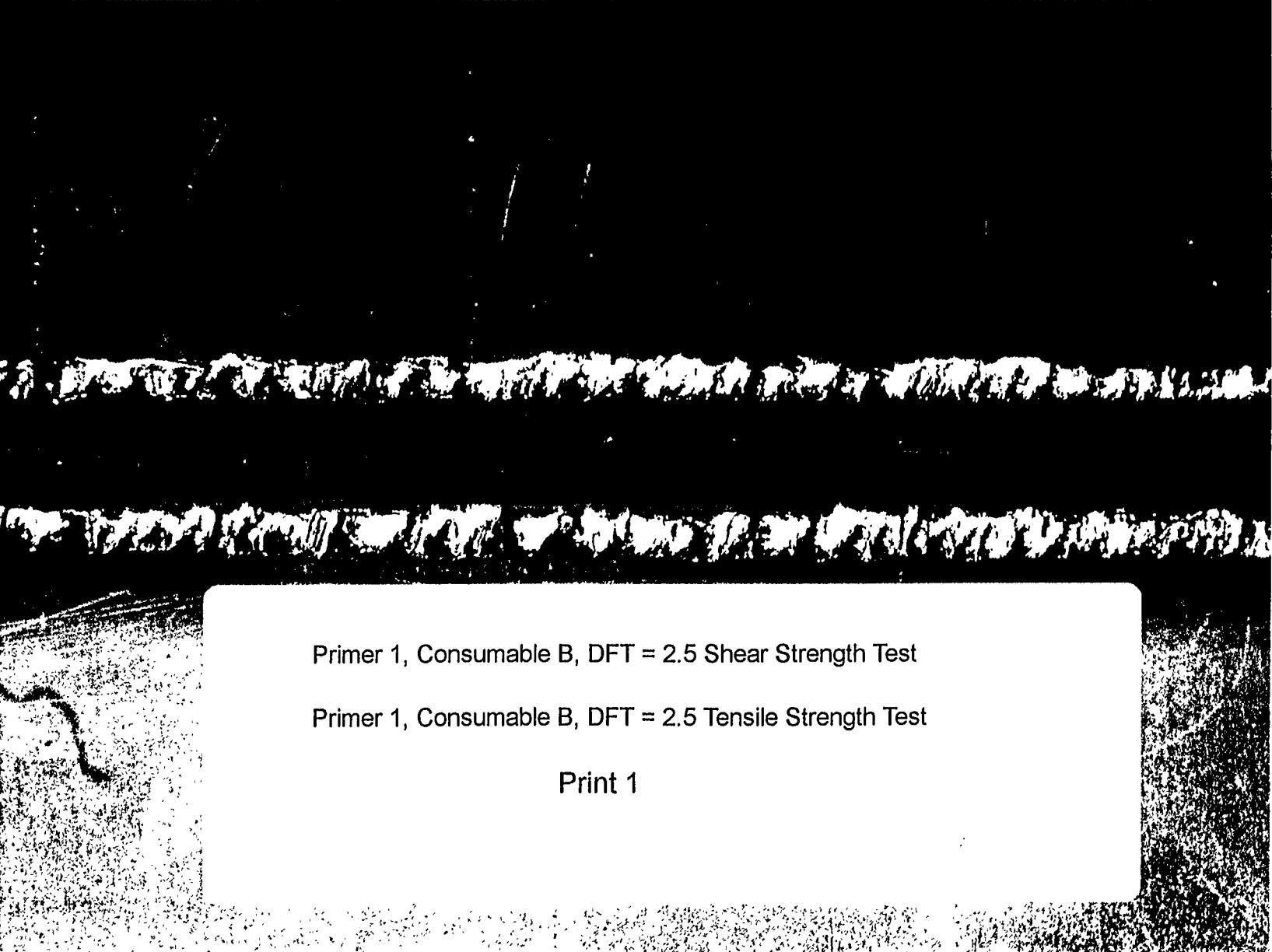
The four photos on the following pages represent three examples of test failure, and one example of a successful weld. The two welds in the first photo, Print 1 on page 48 shows first a weld subjected to a shear strength test which is documented on Table 5, page 39 as Primer I, Consumable B, with a DFT of 2.5 roils, which had a shear strength of 42,032 psi, and an average throat area porosity, $((x+y)/2)$ of 1.27 in². The second weld pictured on page 48 is Primer I, Consumable B, with a DFT of 2.5 mils, recorded on Table 6, page 40 which shows a tensile strength of 64,581 psi, and an average throat area porosity, $((x+y)/2)$ of 1.27 in².

The two welds in the second photo Print 2 on page 49 shows first a weld subjected to a shear strength test which is documented on Table 5, page 39 as Primer I, Consumable A, with a DFT of 2.5 roils, which had a shear strength of 60,288 psi, and an average throat area porosity, $((x+y)/2)$ of 0.92 in². The second weld pictured on page 49 is Primer I, Consumable B, with a DFT of 2.5 roils, which had a tensile strength of 50,276 psi, and an average throat area porosity, $((x+y)/2)$ of 0.42 in².

The two welds in the third photo print 3 on page 50 shows first a weld subjected to a shear strength test which is documented on page A as Primer III, Consumable A, with a DFT of 2.5 mils, which had a shear strength of 60,644 psi, and an average throat area porosity, $((x+y)/2)$ of 0.795 in². The second weld recorded on page 51 is Primer III, Consumable B, with a DFT of 2.5 roils, which had a tensile strength of 51,029 psi, and an average throat area porosity, $((x+y)/2)$ of 0.975 in².

The two welds in the fourth photo Print 4 on page 51 shows first a weld subjected to a shear strength test which is documented on Table 5, page 39 as Primer I, Consumable B, with a DFT of 0.5 roils, which had a shear strength of 65,872 psi, and a passable throat area porosity, $((x+y)/2)$ of zero. The second weld recorded on page 51 is Primer I, Consumable B, with a DFT of 0.5 roils, which had a tensile strength of 48,502 psi, a passable throat area porosity, $((x+y)/2)$ of zero.

48



Primer 1, Consumable B, DFT = 2.5 Shear Strength Test

Primer 1, Consumable B, DFT = 2.5 Tensile Strength Test

Print 1

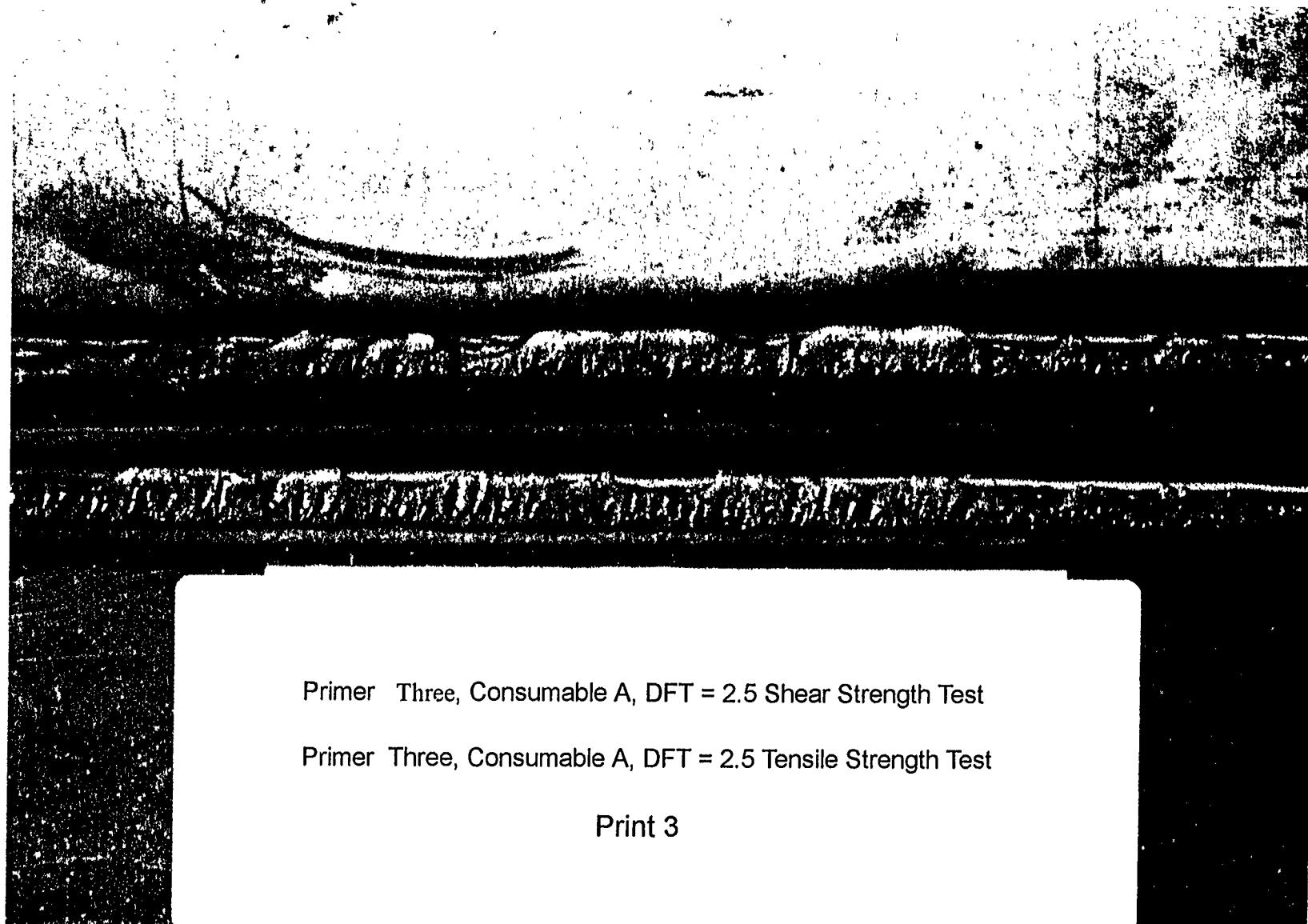
49



Primer 1, Consumable A, DFT = 2.5 Shear Strength Test

Primer 1, Consumable A, DFT = 2.5 Tensile Strength Test

Print 2



Primer Three, Consumable A, DFT = 2.5 Shear Strength Test

Primer Three, Consumable A, DFT = 2.5 Tensile Strength Test

Print 3

51

Primer One, Consumable B, DFT = 0.5 Shear Strength Test

Primer One, Consumable B, DFT = 0.5 Tensile Strength Test

Print 4

SUMMARY

SHEAR STRENGTH TEST

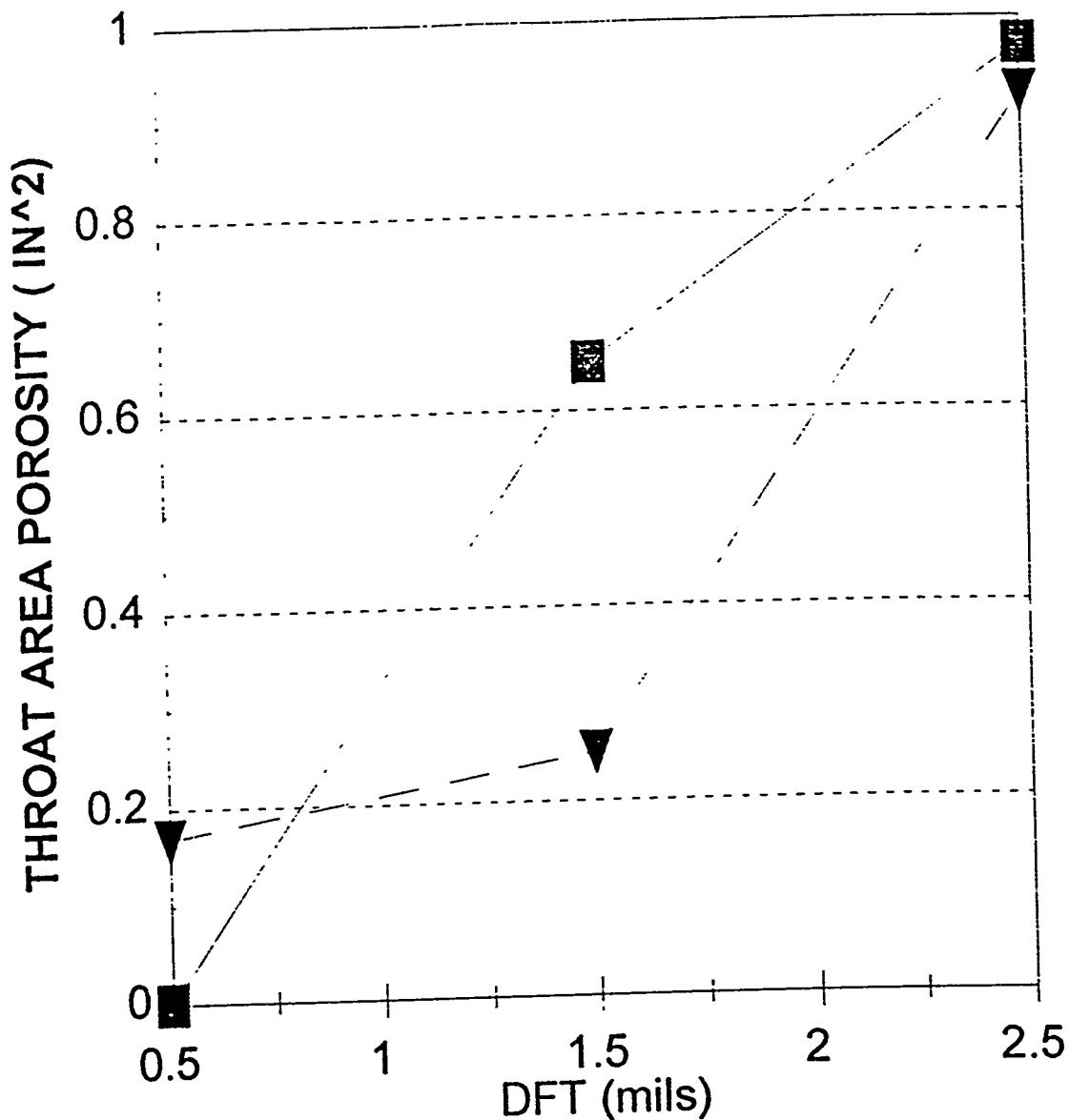
- * The shear strength test specimen that is outlined in AWS B4.0 part E, fillet weld shear test, was chosen to show porosity effect on shear strength. One set of identical weld joints were welded for each primer DFT combination. One set of test specimen are machined according to the requirements for the AWS B4.0 fillet weld shear specimen.
- * Both Primers, I and III, (Consumable A) show shear strength's of 72,647 Lb/in² and 69,761 Lb/in² with 0.5 mils both test dropped over 9,000 Lb/in² of shear strength, (see page 39). Total throat area porosity exceeded 0.52 in² in both test, (page 39).
- * Primer I, welded with consumable A, shear strength drops about 6,000 Lb/in² for each additional 1.0 mil of coating. Primer III, welded with consumable A, shear strength drops over 9,000 Lb/in². Results show with the 1.5 & 2.5 mil test porosity is out of control and shear strength is actually lower with 1.5 mils. It is interesting to observe porosity levels from the fracture tests for comparison. With primers I and III, consumable B shows significant drops in strength also, (page 39) shows the drops in shear strength and the corresponding throat area porosity from the fracture test.
- * Primer II shows interesting results. The pictures taken of the fracture test throat area porosities show increased porosity levels with corresponding increase in DFT, (page 39). However even with a porosity level at 0.33 in² no decrease in shear strength is seen.

TENSILE STRENGTH TEST

- * The specimens were coated to the same target DFT's, (0.5, 1.5, 2.5) for tensile test specimens. From the graphs starting on page 53 no relationship can be found with tensile strength versus film thickness. Even with the heavy porosities that are shown in the fracture test, no tensile results show dropping values with increased DFT. Tensile strength values did not fluctuate more than 6,000 Lb/in², with the extreme case showing the 2.5 mil test with the higher strength.
- * The main idea behind the evaluation of primers at three different film thicknesses is to show the relationships between increased DFT's and the severity levels of porosity produced, (data sheets, pages 39-46). Data collection sheets show increased numbers of porosity with increased DFT in most cases. Calculated throat area is determined with the average porosity, (both spherical and wormhole) diameter and elongation. In every case, but one, with an increase in DFT for each primer there is an increase in computed throat area porosity, (page 39).

FILLET FRACTURE TEST

PRIMER 1

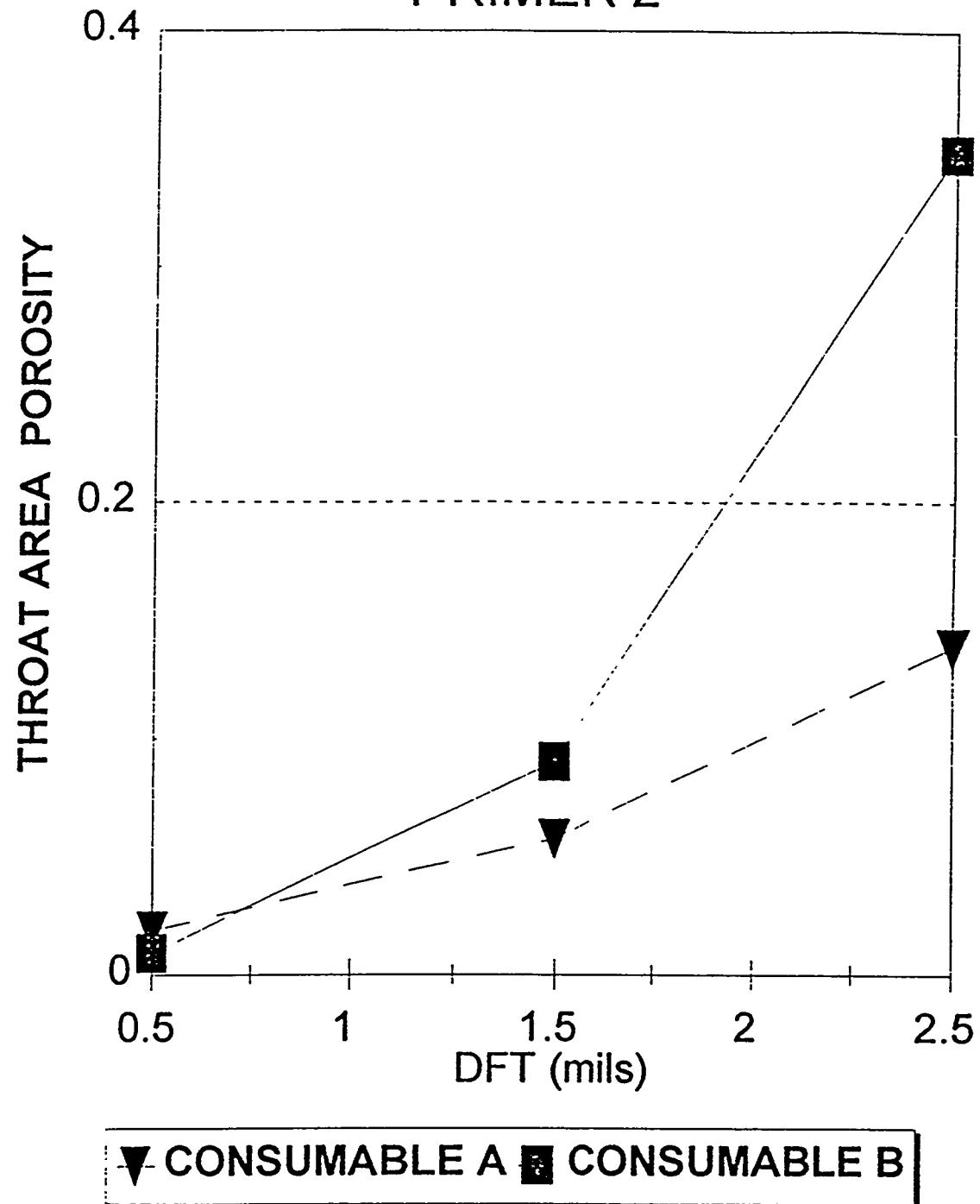


▼ CONSUMABLE A ■ CONSUMABLE B

GRAPH 1

FILLET FRACTURE TEST

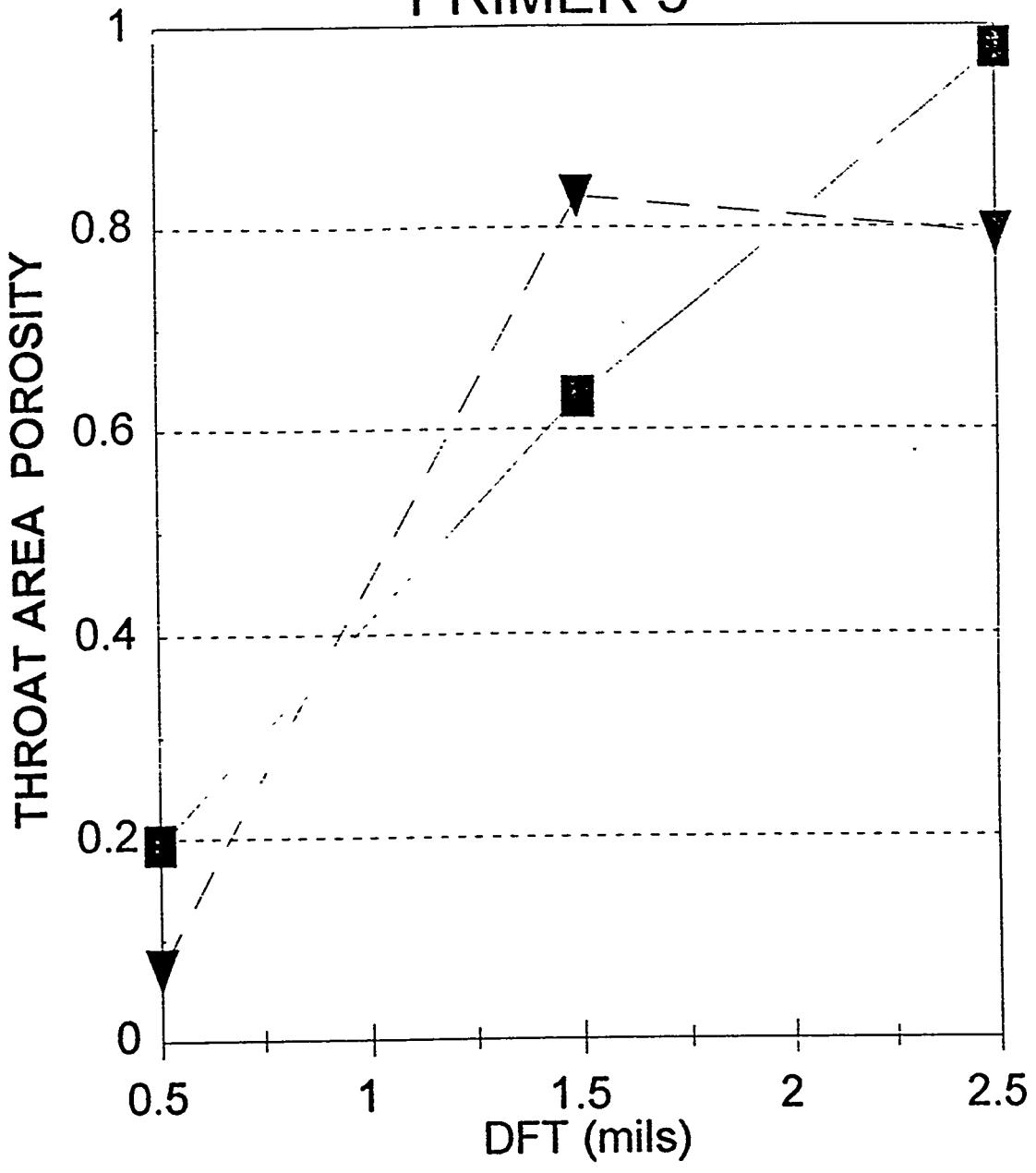
PRIMER 2



GRAPH 2

FILLET FRACTURE TEST

PRIMER 3

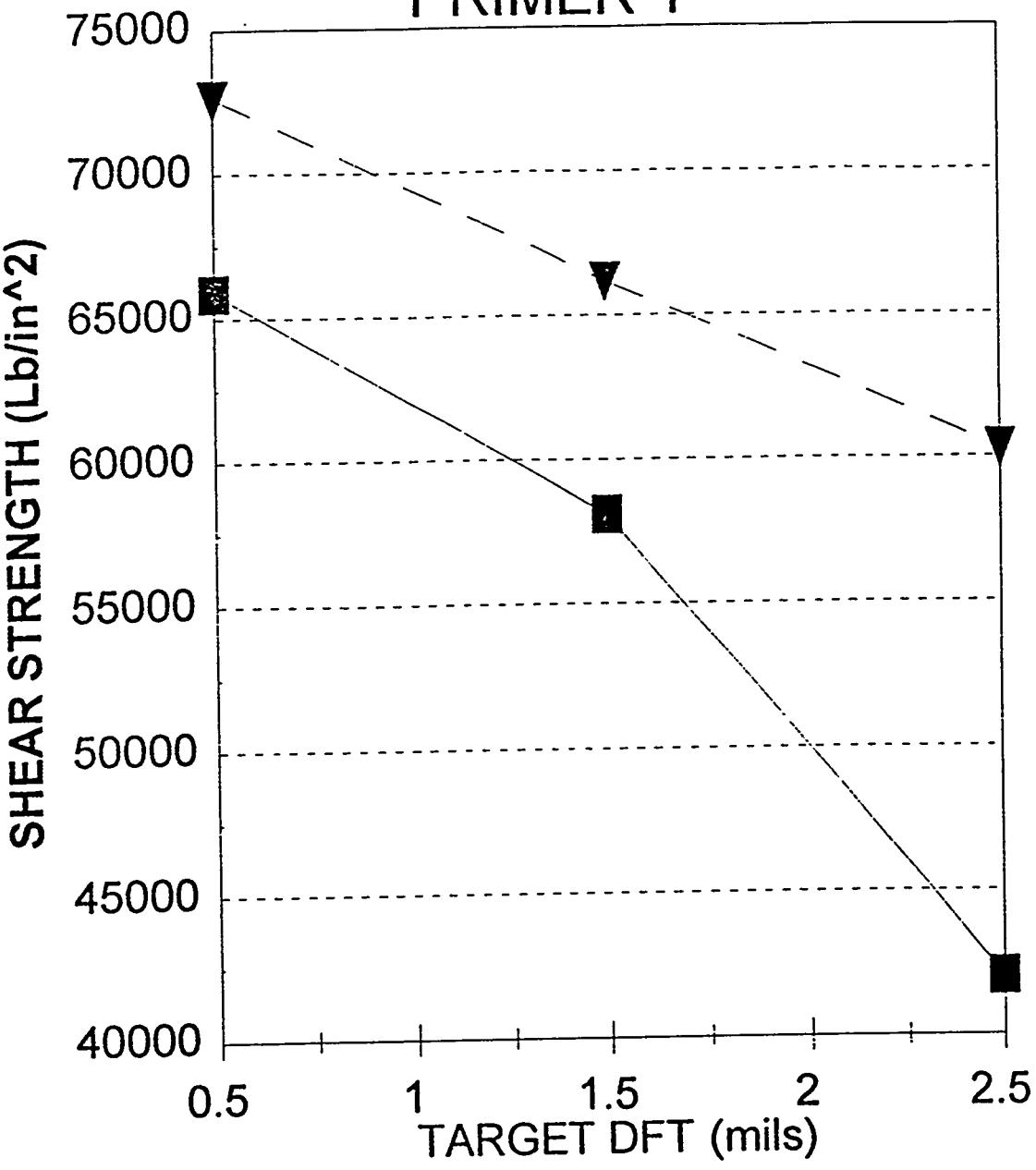


▼ CONSUMABLE A ■ CONSUMABLE B

GRAPH 3

SHEAR TEST

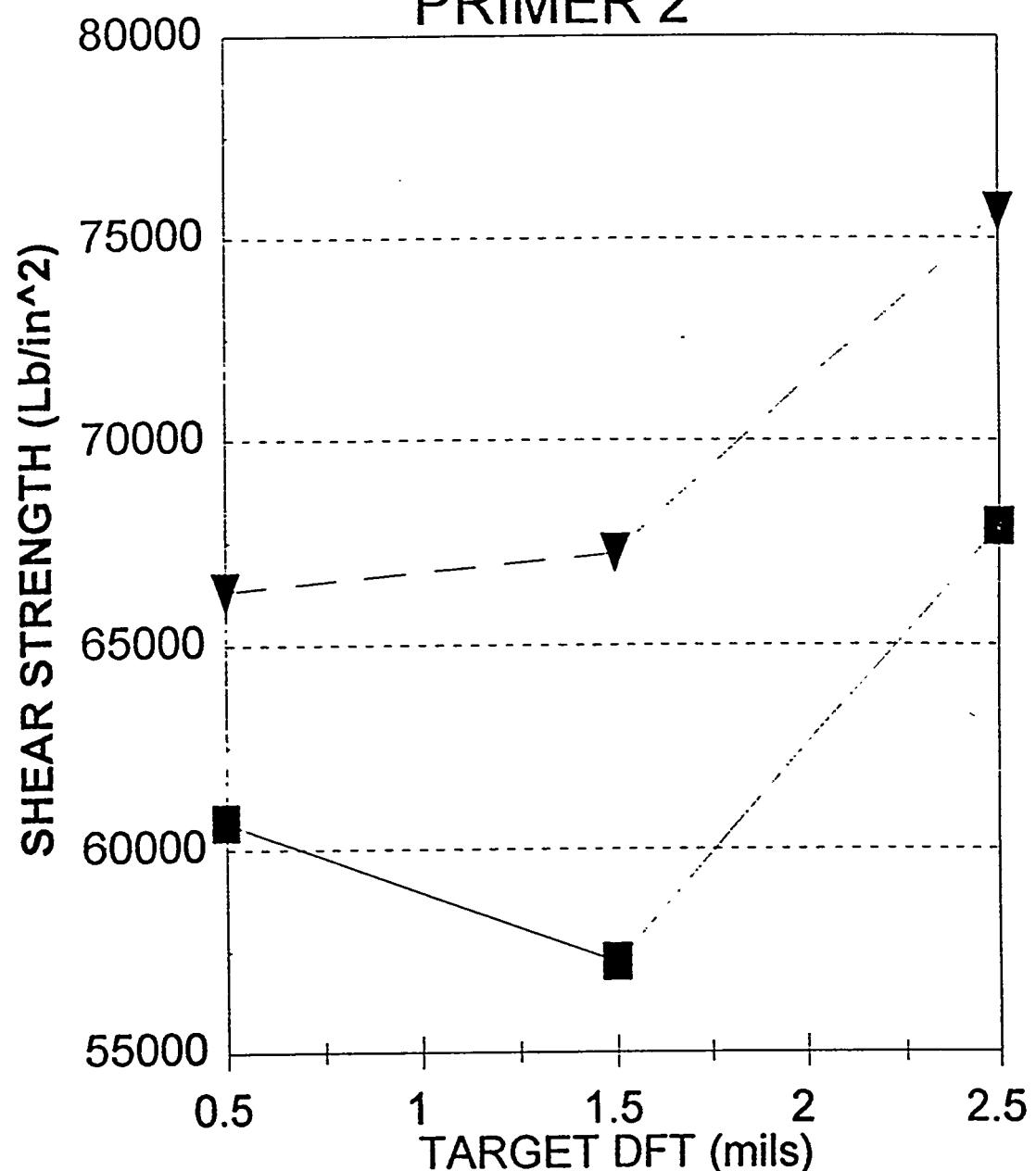
PRIMER 1



GRAPH 4

SHEAR TEST

PRIMER 2

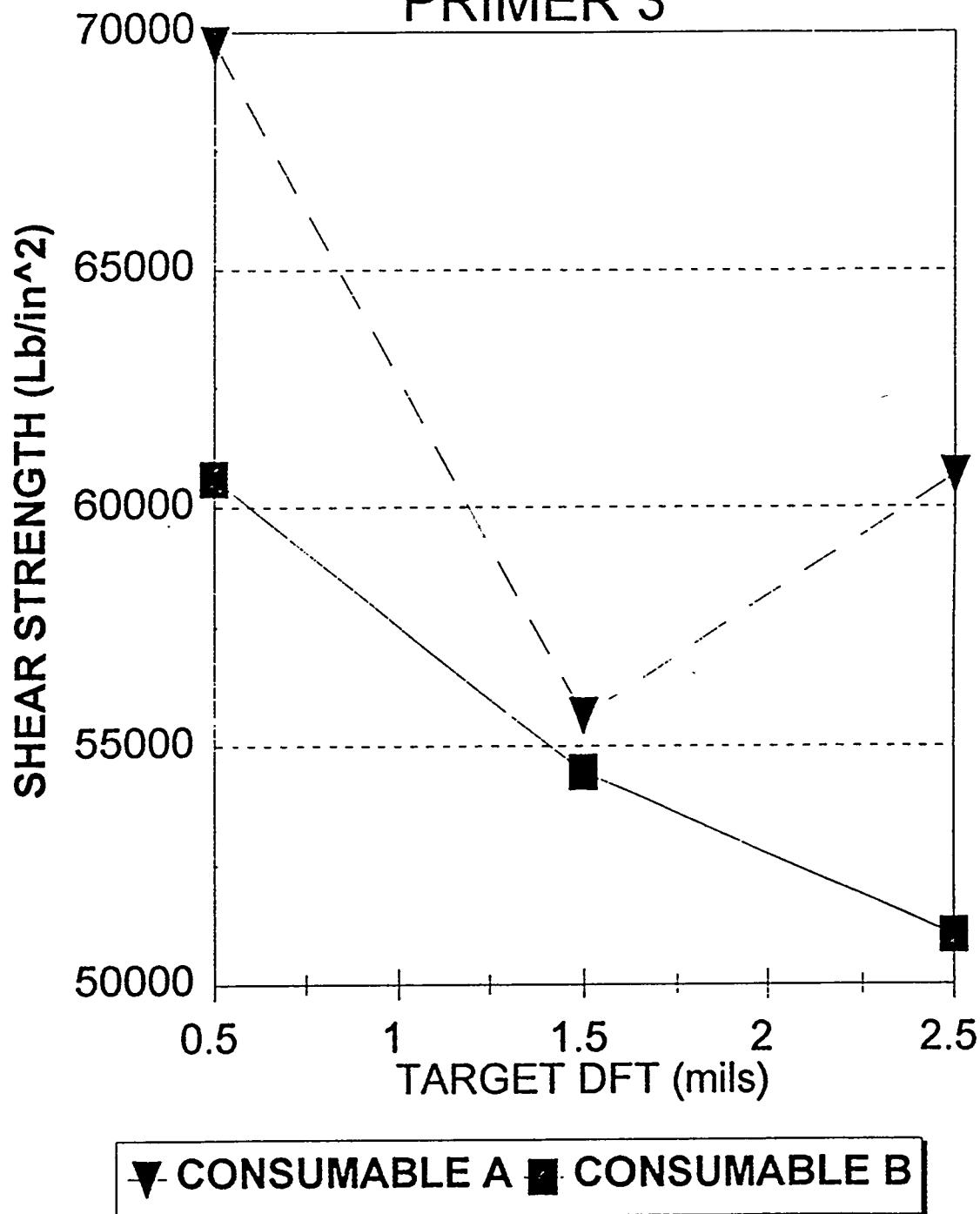


▼ CONSUMABLE A ■ CONSUMABLE B

GRAPH 5

SHEAR TEST

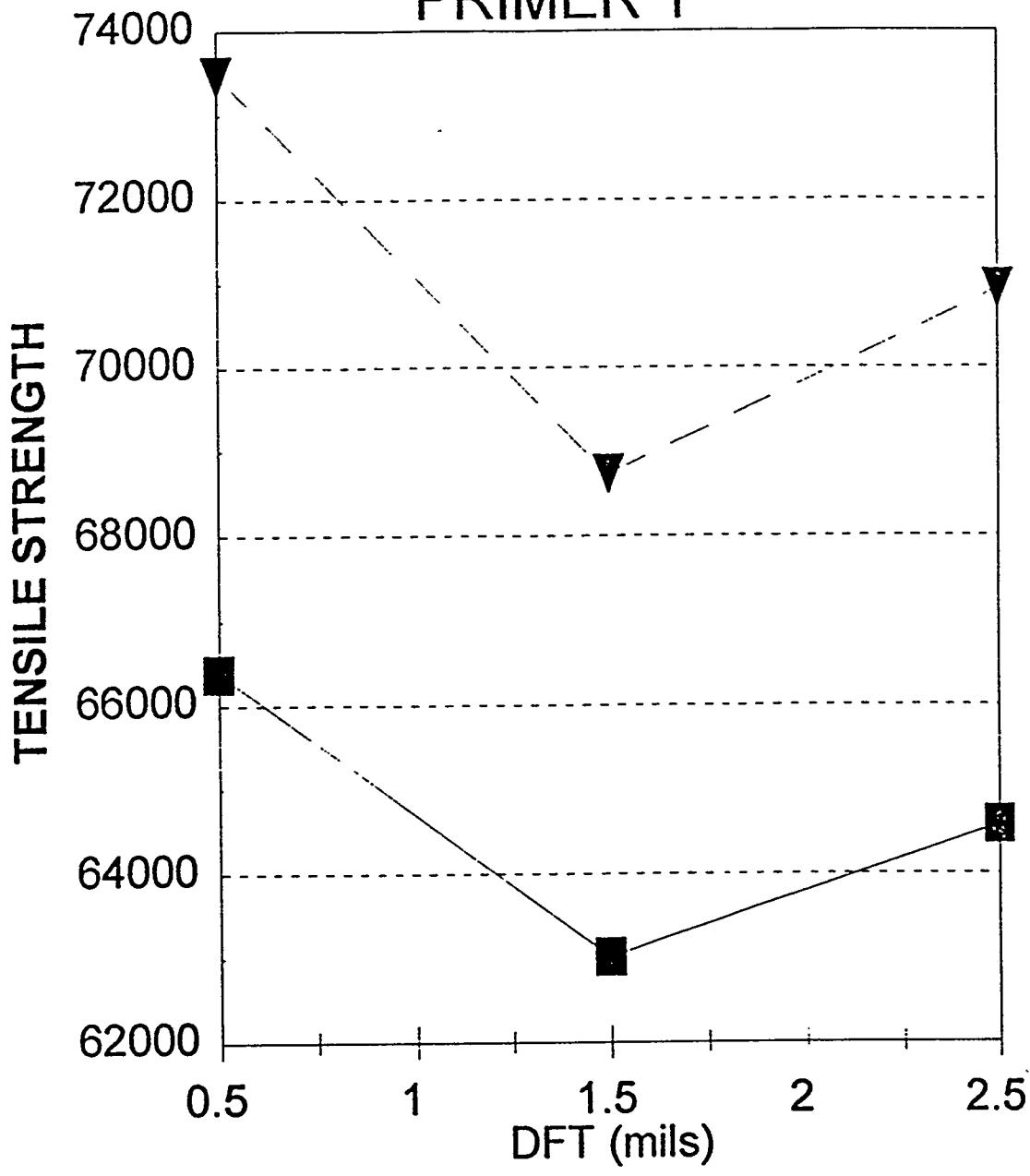
PRIMER 3



GRAPH 6

TENSILE TEST

PRIMER 1

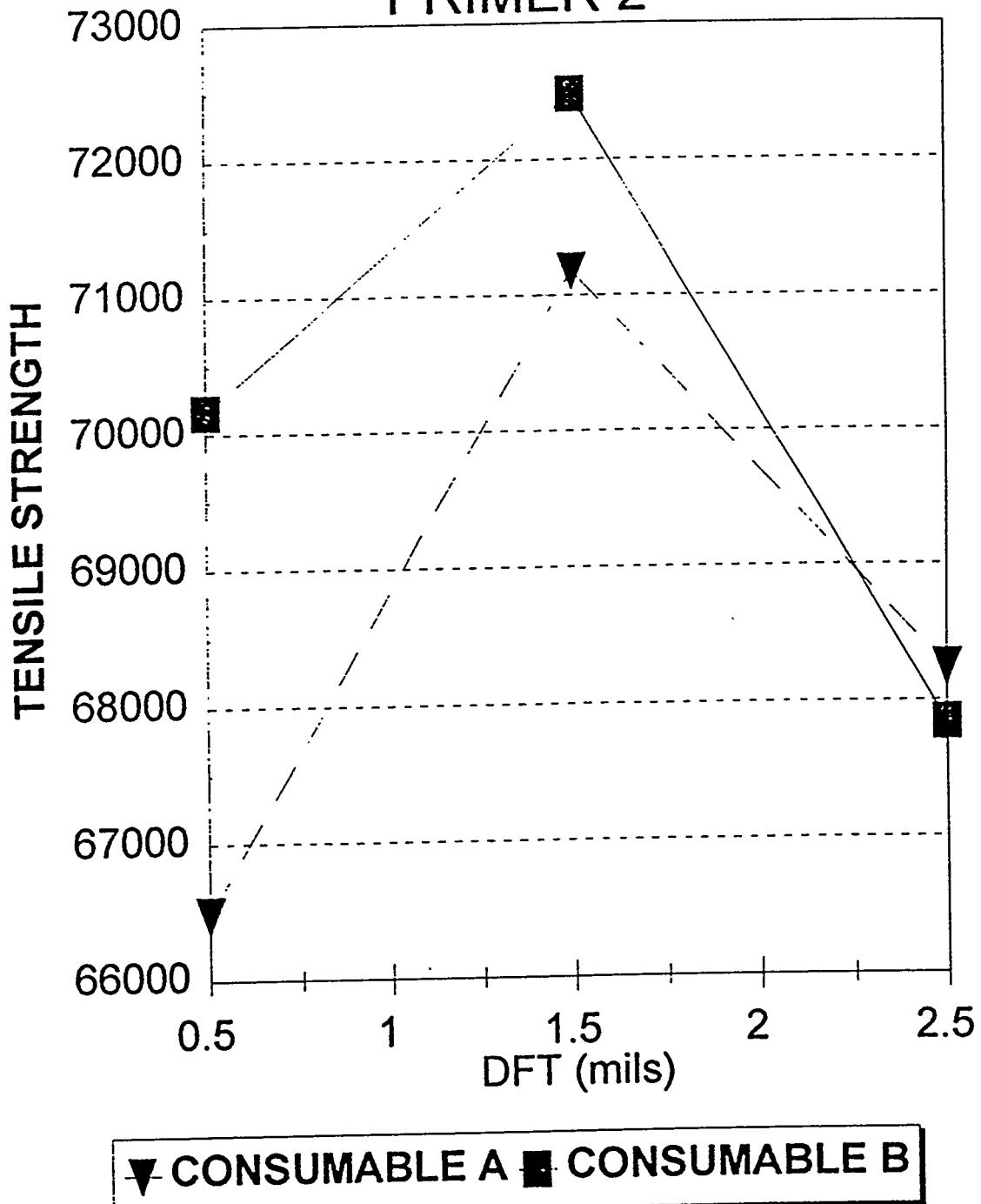


▼ CONSUMABLE A ■ CONSUMABLE B

GRAPH 7

TENSILE TEST

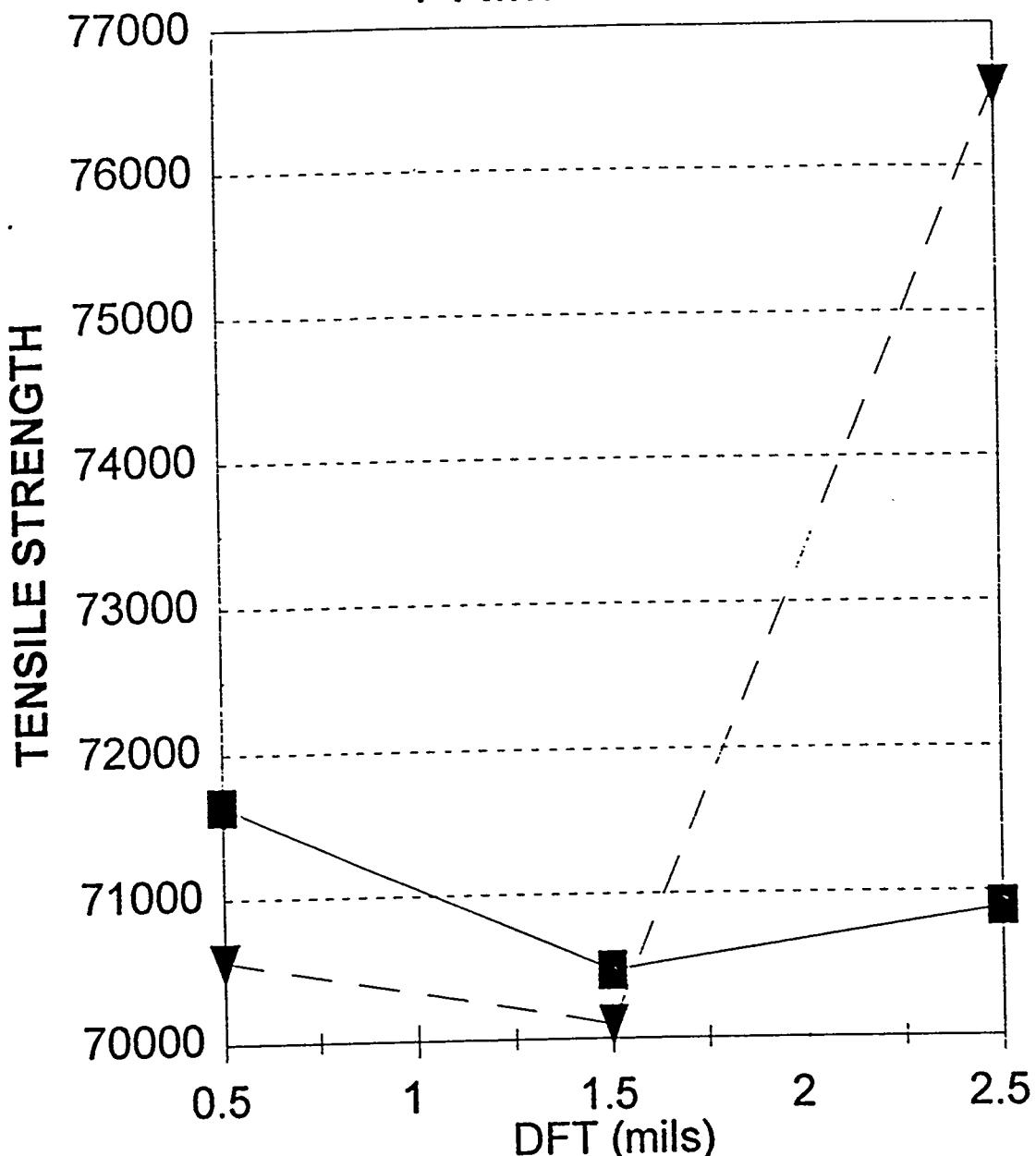
PRIMER 2



GRAPH 8

TENSILE TEST

PRIMER 3



▼ CONSUMABLE A ■ CONSUMABLE B

GRAPH 9

DOCUMENT REVIEW
Weldable Primer for Ship Construction

SSPC PROJECT R037 - WELDABLE PRIMER FOR SHIP CONSTRUCTION

INTRODUCTION

The European and Asian marine industry have routinely used materials called preconstruction primers during fabrication of new ships. These primers are used for two primary reasons:

- * To provide temporary corrosion protection of steel work during the fabrication phase of a marine vessel;
- * To provide a base for the full marine corrosion protection coating system.

Preconstruction primers are also used on many US shipbuilding projects but only the first listed reason for use is effective, the preconstruction primer is generally removed before application of the full protective coating system.

To facilitate the full use of preconstruction primers in ship fabrication, these coatings must meet various criteria, principal is the ability to permit welding of the metal beneath the primer without the introduction of unacceptable weld defects. Therefore the class of preconstruction primers is also known as weld-through primers.

The literature search that was conducted for the NSRP program sought recent information about the use of preconstruction primers in the marine industry. The search was limited to recent advances from the years 1987 through 1992 inclusive. The search focussed on the use of these coatings in both the US and world-wide coating markets.

SEARCH CRITERIA

The search was conducted using combinations of the following keywords:

Primer and/or Coating & Welding &/or Weldable &/or Weld-through &/or Weld-thru &/or Shipbuilding &/or Marine Engineering or Construction or Fabrication.

These keyword strings were used as a whole, in individual pairs and in multiple combinations. The citations were drawn from electronic databases such as NTIS, Compendex, Metals Abstracts, World Surface Coating Abstracts, Chemical Abstracts and similar information services via the Carnegie Mellon University Library system. Duplicate files were discarded and unique items used in the final analysis developed below.

A separate search was also conducted of the literature sources available within SSPC'S library of technical reports, presentations and journal articles.

TOPICS COVERED

The following topics were used to categorize the information obtained:

1. Prevalence of use of preconstruction primers in marine industry:
 - a. US Marine Industry:
 - b. World-wide Marine Industry:
2. Welding Technology and Weldable Primers/Coatings:
3. Quality Assurance & Weld-Through Primers or Coatings.

All citations retrieved and reviewed are included in an electronic database which was used for categorizing and organizing the information. A print-out of the preliminary input of the database is attached. A complete print-out of all recovered articles will be submitted with the follow up report.

1. Prevalence of Use of Preconstruction Primers in Marine Industry

a. The US Marine Industry Practices & Economics

The use of preconstruction primers in the US marine industry is quite different from that found in the world-wide marine market. Such products are used with little frequency in the US. When specified preconstruction priers are often employed for short-term protection of the steel but not as part of the full marine coating system. Prior to application of the full protective coating system the preconstruction primer is largely removed from the steel by sweep blasting.^{1,2} The full protective coating system is only applied after welding and cutting of the steel has been conducted, and after the aforementioned sweep blasting. This results in an increase in the total effective cost of the paint system. An examination of the need for such radical removal of the preconstruction primer was conducted by KTA-

Tator in a project for the NSRP in which the US construction practices were contrasted with those of prevailing in Japanese shipyards.² The conclusion from this study was that the removal of the preconstruction primer was not justified based purely on coating performance. It was suggested that significant cost savings could result from adopting practices for coating of marine vessels under construction prevalent in other countries.^{2,3}

Primer & Weld Quality

The US shipbuilding industry conducts a considerable amount of work on behalf of the US Navy. In Navy work weld-through primers are permitted but the quality requirements of the MIL-STD-248C are perceived to make qualifying a preconstruction primer an expensive undertaking. This standard requires that test specimens be created to establish that the weld quality is not adversely affected by welding.^{4,5} Each preconstruction primer must meet these criteria for weld quality before being allowed to be used.

Primer & VOC

In general when the US marine industry discussed preconstruction primers the reference is to a thin film inorganic zinc coating at 0.8 TO 1.5 MILS, (20 TO 35 pm) total dry film thickness.² The inorganic zinc coating is simply a thinned down version of a normal inorganic zinc rich primer. The impact of VOC emission restrictions is that future preconstruction primers must be derived from water based technology. Current inorganic zinc coatings using an ethyl silicate formulation cannot meet expected VOC level requirements and be applied at the thin film levels required for use as a preconstruction primer.

Primer & Coating System Compatibility

Though much of the preconstruction primer is presumed to be removed before application of the full coating system, vestiges remain. Thus, whatever preconstruction primer is used must be compatible with the finished system, and the intended service.

Primer & Corrosion Protection

The corrosion protection to be afforded by a preconstruction primer in the US is limited to that period from application of the primer to fabrication of the ship. Most of the primer having been removed before application of the full protective coating system, long term protection is unimportant. Typical protective life requirements might be as low as three months.

In conclusion the prevailing practices of the US shipbuilding industry do not favor the use of preconstruction primer, yet do not prohibit such use. The prevailing practices do not maximize the cost saving benefits that might result from preconstruction primer use. The full use of a paint system which maximizes the potential for reducing costs due to rework from hot joining of metal surfaces is needed. This can best be accomplished with a preconstruction primer. Current practices do not identify items subject of unavoidable welding, cutting or other hotwork until after the work is performed. In a study of the influence of coating practices on ship construction costs Peterson Builders concluded for the NSRP that as little as 7.2% of all hotwork needs to be performed at the erection site. Most of joining the and cutting could be conducted before the panel or hull section has

proceeded to blast and paint shop. ⁶ Integration of correctly scheduled hotwork and outfitting with the use of a preconstruction primer could result in significant cost savings for ship construction.

b. World-Wide Marine Industry Practices & Economics

The use of preconstruction primers is very widespread in the marine industry in all countries. Unlike the US, formulations other than inorganic zinc rich, have been used as preconstruction primers for marine coating operations. In Europe the use of an Iron Oxide pigmented Epoxy is not uncommon. ⁷ Despite this, the most prevalent preconstruction primer is still Inorganic zinc rich primer at low film thickness. ¹

The primary advantage of the prevailing practices of the international marine community is the use of a preconstruction primer that plays a role in the finished coating system, it is not merely sacrificed during fabrication. ¹ This results in a significant cost savings for ship construction.

Primer & VOC

The reduced zinc ethyl silicate primers and thin film epoxies used abroad are not amenable to formulation with low-VOC. It is known however that water-based thin film zinc coatings can be formulated. Experience abroad with this type of coating system in ship fabrication appears limited. This suggests that additional testing may be required to qualify thin film zinc coatings based on water-borne formulations.

Primer & Corrosion Protection

The corrosion protective qualities to be provided by weldable primers overseas are of two kinds. Short term protection after application and prior to fabrication. Typical time span 3 to 6 months. Long term protection afforded as a function of the full protective coating system. Time span measured in years, typically one to two years between maintenance.

This results in a need for preconstruction primers overseas that are compatible with a typical full marine coating system.

Primer & Weld Quality

The quality of a weld is critical to the serviceability of a marine vessel. Thus it is no surprise that preconstruction primers are required to pass weld quality tests prior to acceptance in other countries. The Finnish have a typical test, DVS-0501, which seems quite similar to the requirements of the MIL-STD used by the US Navy. Two British Standards have been developed for weldable primers. The first, BS 4129 pertains solely to those primers intended for use on spot welded metal, (resistance welding). ⁸ This standard has little use in the ship construction industry. The second is directly pertinent to the ship construction industry, BS 6084, "Method of Test for Comparison of Prefabrication Primer by porosity rating in arc welding."⁹ The test method is more limited in scope than the corresponding MIL standard used in the US. The choice of submerged arc welding was made because it is a high speed mechanical welding process typical of fabrication in shipyards. Moreover, such arc welding can cause more porosity, regardless of whether the steel is or is not precoated. Only the porosity of the resultant weld is at issue in BS 6084.

Porosities are recorded for the primed welded steel and compared with the weld quality achieved with unprimed welded steel. Presuming a lower quality weld with the primed steel, results are recorded as the difference between the number of porosity events noted for corresponding specimens of primed and unprimed steel. Thus the test clearly attributes any (presumed) increase in weld porosity to the primer. This avoids confusing the issue by accounting for operator dependent weld quality. Porosity events are recorded in two size ranges, between 1 and 3 mm diameter, and those greater than 3 mm in diameter.

The examination of pores in accordance with BS 6084 is performed by radiographic examination, not a visual examination as required in MIL-STD 248C.

The foreword to BS 6084 is particularly revealing as it demonstrates a very different set of assumptions about the effect of welding primers on weld quality and strength, typical of that found in Europe. The reason for this is that it chooses to accept the following premises:

* Weld Strength - Tensile strength is unaffected if the cross-sectional area of the weld is reduced by < 7%.

* Fracture Toughness - Accepts results of previous research indicating that welding primers will have no deleterious effect on the fracture toughness of a weld.

The foreword concludes by suggesting that additional requirements to confirm weld integrity should be established by the specifying authority.

A significant difference in the testing of preconstruction primers abroad is that the primer must also demonstrate convincing corrosion protection along with desirable weld integrity.^{1,7} This is because the primer is intended to be a component part of the total protective coating system. Such corrosion protection tests are typically above and beyond the rigorous testing required of the weld quality produced with the coated steel.

Japanese Methods

During the literature review little information could be garnered about prevailing practices in Japanese shipyards for qualification of weld-through primers. A private communication from a paint supplier did elicit the fact that each yard may have their own in-house procedure for qualification of a preconstruction primer. The main focus is that the weld quality when using a preconstruction primer be within the porosity and strength limits agreed upon for all phases of hull construction.¹⁰

Primer Formulations

Primers intended for use in fabrication require special formulation. Two divergent approaches are taken in the world-wide marine marketplace.

In the Asian shipbuilding market it is typical to use a primer with a high content of organic resin, such as an epoxy. The pigmentation employed can be either metallic or non-metallic, conductivity is not an issue so pigments like red iron oxide are quite common. Primers are formulated for thin-film application. Prefabrication primers based on zinc-rich formulations are also used.¹⁰

In the European market it is more common to use a thin-film inorganic zinc. The pigmentation has historically been a mixture of zinc and conductive filler, such as Iron Phosphide. Recently primers of this type have undergone a significant reduction in the level of zinc used, inorganic conductive extender levels have been boosted to maintain good electrical continuity.

in the Finnish study cited earlier four types of prefabrication primers were examined. one was typical of the organic prefabrication primer popular in thee Asian markets, the remaining three were inorganic zinc primers. The three inorganic zinc primers differed in the levels of zinc employed. From a high of between 60-70% zinc in the first generation material, the two lower zinc primers used 40-50% zinc and 20-30% zinc respectively. Weld porosity measured following DVS-0501 fabrication, (similiar to BS 6084), was inversely proportional to zinc level. At the 20-30% zinc level weld porosity is 01%. This “third-generation” reduced zinc primer was formulated for use with Flux-cored arc welding using electrode materials dispensed from spools, (MIG welding). ⁷

A comparison of the testing requirements from different markets around the world is given in Table 13 below.

Criterion	MIL-STD 248C	BS-6084	DVS-0501
Fillet Weld Specimen	3 ft x 3 in x T-section. Thickness 3/8 in or maximum to be used in production, whichever is less.	1m x 150mm x 150 mm. T-Section. Thickness 12 mm	see Below
Stud Weld Specimen	10 studs	N/A See BS 4129	N/A
Acceptance criteria	< 5 instances 1/16th in (1.5 mm) porosity per inch (1.5% total by volume ; 31% as a proportion of weld length), no pore > 3/32 in (2.5 mm).	suggests less than 7 % total porosity limit .	None given, suggest less than 7 % total
sample Preparation - Fillet Weld	Greatest thickness to be used in production.	6 mm	16 mm in Finnish Test
Sample Preparation - Stud Weld	Reflective of Production - 10 Specimens	N/A see BS 4129	N/A
Examination Method	Visual Micrography	Radiation Micrographs	Visual Micrography
Post Welding Preparation	Gouge first fillet, fracture T from foot of weld.	Remove T down to foot of weld.	Direct Examination

Table 13 - Comparison of Testing Requirements for Weldable Primers US vs World Market

Frequency of Qualification

A difference between each test is the requirement for requalification of a product. This is largely a function of the interpretation of each test method.

The US standard has no standard weld method, nor a standard specimen. It suggest that the primer be qualified on the deepest section, with the largest single pass weld, to be used in actual production. This implies that a primer be re-qualified for each ship to be built.

The Finnish test is a standard welding procedure. When qualified against the test the primer is good with the particular weld technique employed.

The British test uses a standard welding method, and a standard test section. A primer is presumed adequate for use if it passes muster with the suggested welding method, because the chosen method is considered the most prone to inducing pore defects in a weld.

Comparison of Practice US vs World

The world-wide marine industry uses prefabrication primers frequently. The US market uses prefabrication primers infrequently.

The world-wide market retains the prefabrication primer throughout the shop construction process to the greatest degree possible. When removal is required, it is frequently a function of the service to which the plate steel shall be subjected. For instance, removal is common from plate steel destined for cargo holds or ballast tanks when a primer compatible with the fluid service is needed. The US market routinely removes the prefabrication primer if ever it is used, adding to the total cost for ship fabrication. It should be noted that this is not a black and white issue, removal of prefabrication primers is known in both US and European or Asian markets.

The international standards for weldable primer qualification are standardized, the US standard, MIL-STD 248C is not.

The use of prefabrication primers overseas is more common because of:

- Standardized Qualification Procedures;
- Higher VOC Limits;
- Greater User Acceptance

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